SURVEY OF MODERN ENGINEERING MATERIALS AND MACHINABILITY.

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IT has been said by one of our wisest men that the accumulation of knowledge consists in getting to know more and more about less and less. The more and more bit is obvious enough, but in these days the less and less part is difficult to appreciate—particularly when you begin to prepare a survey of modern engineering materials. The title for my paper was chosen with more haste than discretion, for want of a better, and when contemplated in cold blood it is fearsome in the immense range of materials it should cover. It should embrace the materials used for ships' propellers, which must retain their toughness in the low temperatures of the icefields of the Antarctic, and should give honourable mention to the alloys of high magnetic permeability which are used in audiophones for the relief of the partially deaf. However, the title of my paper has its compensations because, if we take it for granted that I must limit myself to a few materials, it follows that I have a pleasanter task than that of an author who is tied to a very definite subject.

In modern engineering the factors which govern the selection of a suitable material for a particular part are many and varied and in arriving at his decision on this matter, the designer has to give one or more of the following points his careful consideration: (1) The duty of the part. This includes all questions of (*a*) stress; (*b*) pre-determined factor of safety; (*c*) resistance to wear; (*d*) resistance to corrosion; (*e*) the effect of heat. (2) Weight. (3) Cost of manufacture. (4) The shape of the part.

If it is borne in mind that most of these factors may, and often do, effect a particular part at one and the same time and that, in addition, some of them are capable of further sub-division, it will be realised that the choice of a material which will give satisfaction is in many cases no easy task. There is no doubt, however, that the difficulty has been minimised by the fact that metallurgical research has kept pace with the advances in design and the engineering industry owes much of its progress to those men who have devoted their lives to the study of metals and their properties. On the other hand the demands of designers have been the main

impulse behind that research and engineers have therefore been partly responsible for the great developments in the science of metallurgy.

One point in this connection requires some emphasis here, and that is the wealth of technical information which has to be collected about a particular material before the full extent of its usefulness in industry can be determined and its limitations appreciated. Tensile strength, fatigue resistance, ductility, specific gravity, chemical composition, method of manufacture, machinability, coefficient of expansion, electrical and thermal conductivities—all these and many other details are required by engineers; and not only must these particulars be available for ordinary atmospheric conditions but many of the properties must also be known for special conditions—whether it be a question of tensile strength at 800 degrees C. or resistance to shock at temperatures below zero.

As a result of the developments in engineering and in metallurgy, two very natural things have happened. The first is that, because of the limitations of the human brain, the wise metallurgist now specialises in one particular branch of his subject, just as the wise engineer specialises as far as modern industrial conditions will permit. The second result is the evolution of such a wonderful series of materials and alloys that even to prepare a list of them would be a colossal task.

The element nickel takes precedence over all others in the amazing range of materials with remarkable properties which it has made available for every engineering industry. The electrical and automobile industries in particular have been specially favoured by this king among metals.

The alloys of iron and nickel have received the attention of investigators during several centuries owing to their presence in appreciable quantities in meteorites. Of the known meteorites over one-third consist almost entirely of iron and nickel while most of the others contain considerable percentages of these metals. Very rarely has a meteorite been found which contained no nickeliferous iron. These heaven-sent masses of metal were used to make implements of various kinds and something was learnt of their mechanical properties. But although prehistoric man may have chased his prehistoric wife with a nickel alloy club fashioned from these astronomical curiosities, it is only within very recent times indeed that the properties of these alloys have been properly appreciated and they have been applied to less satisfying but more useful purposes.

When man first began to build metal structures and machinery he had at his disposal only cast iron and wrought iron. Cast iron had some strength and when chilled had considerable hardenss, but at best it was a brittle material. In wrought iron considerable

toughness was obtainable but its tensile strength was low. Mechanical development was therefore restricted to the use of slow moving and relatively massive parts.

Bessemer, Siemens, and others, altered the situation by showing how steel could be made in large quantities at a low price. Carbon steels immediately provided quite a wide range of properties which were controlled by varying the carbon content and the method of heat treatment. With the passage of years, however, the demand was for higher and higher strengths while retaining a measure of toughness and keeping down the cross-sectional area—in other words for a higher strength/weight ratio. An increase of the carbon content of plain carbon steels to obtain greater strength was unfortunately always accompanied by a rapid fall in ductility and an increase in the brittleness. This was a very serious drawback indeed because ductility and toughness are essential to high tensile steels in many applications, the requisite toughness having a two-fold virtue, first in resisting shock, and secondly in resisting the propagation of a crack formed by the local failure of the part. Any occurrence giving rise to a crack may not be disastrous if the crack can be prevented from spreading, but if the concentration of stress at the base of a crack cannot be resisted then the failure of the component may take place very quickly.

Various methods have been suggested for measuring the resistance of materials to shock but in the case of steels the most generally accepted is the notched bar impact test. The form of it devised Izod is employed in this country and the toughness of the material is expressed as the number of foot lbs. absorbed when a falling pendulum of 120 ft. lbs. capacity breaks a test piece of 10 m.m. square section notched to a standard depth. An ordinary grey cast iron gives such poor impact figures that it has practically no toughness as measured by this method. Good quality alloy structural steels give over 30 ft. lbs. Izod impact value, and tough steels may give up to and over 100 ft. lbs., e.g., the core of a good quality case-hardening mild steel of light section satisfactorily heat-treated will give 100 ft. lbs.

TABLE NO. 1.

COMPARISON OF MECHANICAL PROPERTIES OF CARBON AND NICKEL STEEL (1) NORMALISED, AND (2) HEAT-TREATED TO SAME TENSILE STRENGTH

COMPOSITION (per cent.)				MECHANICAL PROPERTIES Normalised					MECHANICAL PROPERTIES Heat-treated				
C	Si	Mn	Ni	Y.P.	M.S.	E.	RoA	Izod	Y.P.	M.S.	E.	RoA	Izod
.33	.15	.63	nil	23.0	35.4	p.c. 31	p.c. 59.5	24, 23	?	52.8	p.c. 16	p.c. 43	10, 11
.33	.13	.63	3.28	28.0	47.7	23	54.6	32, 32	43.2	52.9	25	64.9	100, 104

The demand for high tensile strength combined with high impact value has been met by the addition of alloying elements to steel and particularly by the use of nickel. Nickel dissolves in and strengthens and toughens the pure iron or ferrite constituent of steel. It refines the steel structure, i.e., it reduces the grain side and as distortion under stress is in the beginning the result of crystal slip, this refining increases the resistance to that slip. Further, it has a great influence on the effect of heat treatment—especially in increasing the depth hardening properties of steel and that is a sufficiently important matter to merit consideration at this stage.

All steels have a definite temperature (dependent on the composition) above which the carbon forms a solid solution in the iron. That is known as the critical temperature and the physical properties of the metal can be varied by the method of cooling from that temperature. If the steel is " hardened " by cooling quickly (e.g., in oil or water) from a few degrees above its critical temperature, it may then be " tempered " to increase the toughness by reheating to a temperature lower than the critical and cooling as determined by the composition and other factors. In this way one steel can give a whole range of properties. A 3½ per cent. nickel steel can be heat-treated to give a tensile strength of 90 tons/sq. in. with an impact value of 10 ft. lbs. or alternatively to give a tensile strength of 50 tons/sq. in. with 60 ft. lbs. Izod. Now although much work has been done (and the results published) on the effect of the mass of the component on the physical properties obtained by heat treatment, the facts have not been satisfactorily appreciated by all concerned. With carbon steels the core of heavy sections simply will not respond to the quenching treatment because a carbon steel must cool quickly before the optimum properties are developed and the core of these heavy sections of necessity cools slowly no matter how drastic the quenching treatment is, with the result that only the metal near the surface has the required properties. Often too the quenching cannot be drastic and in the old days certain medium carbon steels of the " 40-ton " variety gave sleepless nights to engineers and metallurgists alike. In many applications because of the heavy section oil-quenching was no use and because of changes of section and stamping folds water quenching produced cracks. It was here that nickel and other alloy steels came to the rescue. Before passing on however one point arising from these comments on mass effect requires emphasis. The B.S.I. material specification figures are, unless otherwise indicated, obtained from 1½-in. diameter test pieces and as such constitute a valuable and general guide to engineers, but to base design on the universal test piece without applying due thought to the section is to court disaster.

The effect of nickel on steel having been described we can now introduce that other valuable alloying element, chromium.

Chromium combines with and strengthens the carbide constituent of steel and, as we have noted that nickel combines with the iron, it follows that the use of nickel and chromium together gives better physical properties than when either is used by itself. Chromium, like nickel, reduces the rate of cooling necessary to get adequate hardening of the steel. This makes the nickel chromium steels especially suitable for large sections requiring heat treatment by giving them deep and uniform hardening power. They require greater care in forging, stamping, and heat treatment than do the plain nickel steels but give greater strength and toughness when properly selected and treated. A steel with 3½ per cent. nickel and 0.75 per cent. chromium will give over 35 ft. lbs. impact value in conjunction with a tensile strength of 60 tons/sq. in. and, if a small percentage of molybdenum is present, sections up to 5½-in. in diameter will give uniform test results in the very core.

The addition of the molybdenum has a dual purpose because in addition to still further increasing the depth hardening properties of the steel,it ensures complete freedom from temper brittleness. Without the molybdenum content it is an unfortunate feature of nickel-chromium steels that they may become very brittle if the tempering operation is not carried out very carefully. Any interruption of the speed of cooling from the tempering temperature may reduce the impact value to a dangerous degree. Although rapid cooling in water does much to avoid this danger, the presence of molybdenum is the most valuable safety factor.

TABLE NO. 2.

PHYSICAL PROPERTIES OF ALLOY STEELS.

Steel	Carbon	Man'ese	Nickel	Chro'm	Moly'm
A	.38	.65	—	—	—
B	.38	.5	3.	—	—
C	.30	.5	3.5	.7	—
D	.30	.5	3.5	.7	.2
	Y.P.	M.S.	E	RoA	Izod
A	28	46	p.c. 16	p.c. 28	24
B	47	55	23	63	48
C	55	60	22	63	72
D	65	70	20	59	55

As this paper is not intended to be a catalogue of different alloy steels and their alleged properties on which further information can easily be obtained by turning to modern works of reference, it will suffice if I conclude this chapter with the statement that, by judicious selection of alloying elements and appropriate heat treatment, tensile strengths up to and over a 100 tons/sq. in. can be obtained and the toughness need never fall below 30 ft. lbs. Izod value, while the cross section of the component no longer plays the rôle of the nigger in the wood pile.

The wearing properties of steel and their surface hardness have not lacked attention in the last few years and the alloying elements already mentioned have been used to improve case-hardening steels to withstand the very arduous conditions prevailing, for example, in the gear box of a modern automobile ; and later in your session I understand a paper will be read on the new ammonia or nitride-hardening process which therefore will not be further described in this one. But the usefulness of one other type of gear steel is worthy of note.

As already indicated, the addition of nickel and chromium to steel reduces the rate of cooling necessary to get the steel fully hardened and as more and more of these elements are added a stage is reached at which the cooling can be done in still air and no quenching in a liquid medium is necessary. These air-hardening steels are naturally of great value for parts where distortion must be avoided and even when the Brinell hardness is over 440 (corresponding to a tensile strength of over 100 tons per sq. in.) the toughness of the material remains remarkably good. The two objections to this steel are the difficulty of machining even in the annealed condition and the pitting to which the gears are prone in service if tooth pressures are high.

The resistance of steels to corrosion and to the effect of heat is an enormous subject in itself as the result of developments in the last decade. Even the ordinary mild structural steel beloved of public works contractors has been improved by the addition of copper which gives, at slight increase of cost, a tensile strength well over 30 tons/sq. in. with twice the normal resistance to atmospheric corrosion. The 12 per cent. chromium iron alloys which first astonished the engineering world as stainless steels, while still giving useful service, have been eclipsed by alloys with still more amazing indifference to corrosive influences of all kinds, while in the field of resistance to oxidation and scaling under the influence of heat we now use as a matter of course nickel chromium alloys which will resist a bright red heat almost indefinitely when ordinary carbon steels and ordinary cast iron would disintegrate in a few hours.

These heat-resisting alloys are of several distinct types, one of

which has several points of interest from the point of view of engineer and metallurgist alike. I refer to the so-called austenitic steels about which some considerable confusion of thought appears to prevail. Pure iron has two well-defined crystal structures. It possesses one structure at ordinary temperatures called α iron which is magnetic. If the temperature is raised high enough a critical point is reached at which the structure of the iron changes completely to δ iron which is non-magnetic. The addition of other elements reduces the temperature at which this change takes place and we find that by increasing these additions of say nickel, the change point falls lower and lower until finally it is below atmospheric temperature and consequently the alloy is non-magnetic at room temperatures and the iron is in the δ condition. One result of this is that these alloys cannot be hardened by heating and quenching and the only method of increasing their tensile strength is by the application of some kind of cold work in the form of bending, drawing, hammering, or other deformation. Such cold working, however, tends to break up the iron into α again with consequent return of some of the magnetic properties and general reduction of efficiency for electrical and corrosion resisting purposes.

In addition to their non-magnetic, corrosion, and heat-resisting properties these steel have remarkable strength at high temperatures and therefore find favour for many high duty purposes in spite of their cost.

TABLE No. 3.

TENSILE STRENGTH OF STEELS AT ELEVATED TEMPERATURES.

Maximum stress in tons per square inch.

STEEL :	600° C.	650° C.	700° C.	750° C.	800° C.	850° C.	900° C.	950° C.
Three per cent. Ni-Cr ...	34.0	23.6	13.5	11.2	9.2	6.9	4.5	—
Stainless ...	24.2	17.3	10.2	8.0	6.1	5.6	3.9	—
Silchrome ...	42.0	34.5	25.3	17.3	10.7	7.2	3.9	3.0
High Chro'ium	36.5	30.0	19.0	13.0	7.0	7.2	7.3	5.2
Cobalt-chrome	45.0	30.5	24.8	13.6	10.0	5.8	8.1	6.0
High-speed ...	41.0	26.6	21.3	16.8	9.8	7.7	8.5	5.6
High nickel-chrome ...	42.6	38.3	33.8	28.6	24.0	19.4	12.5	12.5

Almost all the known elements have been added to steel to produce alloys with special properties and the discoveries patented. Some increase the ease of heat-treatment, some improve the working properties, some confer special electrical or magnetic qualities, and some do nothing but demonstrate the existence of unscrupulous metallurgists who are willing to prostitute their profession for sordid monetary gain.

The three most important ferrous materials other than wrought steel are cast steel, cast iron, and malleable iron. Considerable advances have been made lately in the production of the first two, but malleable iron has unfortunately been rather left behind. To manufacture consistently a malleable iron with a tensile strength of 20 tons/sq. in. and reasonable ductility still requires careful selection of chemical composition, careful control in annealing and the assistance of Providence. Surprisingly little success has attended experiments with the addition of alloying elements and it need detain us no longer.

Cast steel on the other hand has responded to the addition of alloys remarkably well and we find a range of tensile strengths available which has extended its field of usefulness and rendered it amenable to heat treatment. Cast steel parts suitable for heat treatment can now be produced to give a tensile strength up to 50 tons/sq. in. with an impact value of 40 ft. lbs.

Cast iron, however, shows the most remarkable improvement of all the cast materials and I propose to devote a little more time to the causes of its restoration to favour.

Ordinary grey cast iron has benefited from improvements in control of composition, melting procedure, and the addition in certain cases of alloying elements such as nickel. The result has been sounder castings, higher tensile strength, freedom from chill and uniformity of structure through thick and thin sections. These changes are important but not so revolutionary as others to which I would like to draw attention.

The use of cast iron for many parts in furnace work and similar applications was in the past seriously restricted by its tendency to growth and scaling. It was the cheapest of all structural materials but gave most unsatisfactory results when subjected to no more than moderately high temperatures. Surface oxidation in the form of scaling is too familiar a phenomenon to require explanation but the mechanism of growth in cast iron is not so generally understood and, when it is borne in mind that under appropriate conditions a grey iron will increase in volume up to as much as 30 per cent., an explanation of this peculiar property is of more than passing interest.

The carbon content of a typical cast iron is of the order of three per cent. which is considerably in excess of the amount which the

iron is capable of holding in solution. As a matter of fact in good grey iron only about .6 to .8 per cent. of the carbon is in the combined form and the remainder exists as free carbon or graphite distributed throughout the metal in the form of flakes. These flakes of graphite give the iron its familiar grey colour when fractured and although they give grey iron its well-known wearing properties by providing graphite lubrication, they are nevertheless the explanation of the weakness of the iron as a structural material and in addition are the primary cause of growth. For when the iron is heated from cold, small internal cavities are formed round the graphite flakes as a result of the differential expansion of iron and graphite. This means that at high temperatures oxidising gases get easy access into the metal where they proceed to oxidise the iron in the cavities at and near the surface. After a time the oxide layer in these cavities becomes sufficiently thick to stop further oxidation but on cooling the scale so formed stops up the cavities and retards normal thermal contraction. Local stresses are set up which increase as the temperature falls and the iron becomes increasingly brittle. A stage is reached at which the stresses are high enough to produce minute fractures which, of course, start adjacent to the graphite flakes near the surface. When quite cold it is found that the iron has grown slightly as a result of the presence of oxide and small cracks. On reheating the process continues and the small cracks open out to let the oxidising gases still further into the iron. When the cycle is repeated often enough the iron becomes distorted, swollen, brittle, and useless.

However, there are now three forms of iron available which do not grow. One is old and two are new. The old one is the least satisfactory and we know it as " white iron." It contains practically no graphite flakes because, as the result of rapid cooling from the casting temperature, most of the carbon is in the combined form, but it is hard, unmachinable, brittle, and scales rapidly. That last point is important. Scaling can take place without growth just as growth in other irons can take place without the appearance of much surface scale. A white iron with a total carbon content of 2.6 per cent., silicon .6 per cent., and manganese 1.6 per cent., does not grow at 900 degrees C., but it scales fairly quickly.

The other two non-growing irons are of much greater importance. The first owes its popularity to the discovery that, although small additions of silicon tend to increase growth, a point is reached beyond which the added silicon retards growth, and irons marketed under the name of Silal containing between five and 10 per cent. of silicon are practically immune from the trouble. The higher the silicon, however, the weaker and the more brittle the iron and the minimum should be used with due regard to service temperature. On the other hand the silicon must be adequate to resist growth at

the particular service temperature because, if not, its lack of strength and ductility will actually cause it to fail even more rapidly than an ordinary iron. This fact has been responsible for disappointing results experienced by engineers who under-estimated the temperature to which their structures were subjected.

The second type of non-growing and heat-resisting iron bears a close resemblance to austenitic steel and is in fact called austenitic cast iron although particular brands are marketed under names like Nimol, Niresist, and Nicrosilal. The last of these is produced by the addition of approximately 14 per cent. of nickel, six per cent. of copper, and three per cent. of chromium to the Silal already described and is worthy of extended trial for firebars, stoker links, carburising boxes, metal and salt melting pots and similar parts.

These irons, like the corresponding steels, are non-magnetic and one of them containing 10 per cent. of nickel and five per cent. of manganese has found use in huge quantities in the electrical industry for resistance grids, alternator castings and switch gear castings of all kinds. It is cheaper and much more adaptable than the non-ferrous alloys of brass and bronze which were formerly used and new jobs are being found for it every day.

Before leaving cast iron I want to refer briefly to the question of its heat treatment. Most of the experiments in this direction have been carried out in connection with the piston rings, valve inserts and cylinder liners of internal combustion engines and a great deal has yet to be done. In addition many of the alleged advantages of the process are still the subject of controversy unseemly in its violence, but one or two salient points have been satisfactorily settled. The only cast irons which respond satisfactorily to heat treatment are first class quality grey irons with low silicon, sulphur, and phosphorus, and combined carbon ranging between .5 and .9 per cent. The effect of alloying elements corresponds closely to the effects of similar additions to steel and the actual hardening operation is carried out in the same way as with steel. However those cast irons which lack sufficient nickel and chromium to make them air-hardening are quenched in oil because as one might anticipate from the nature of the material, water quenching is disastrous. Brinell hardnesses of up to 500 are readily obtainable in the fully hardened condition but the effect of mass is even more pronounced than with steel; but the greatest difference between heat-treated cast irons and the corresponding steels lies in the fact that cast iron in the fully-hardened condition with the high Brinell hardness mentioned, shows a tensile strength actually lower than in the "as cast" condition. A low temperature tempering operation is absolutely essential to restore the tensile strength and this can be effected with practically no loss of Brinell hardness. As an example of this a grey iron containing 3.0 per cent. carbon, 1.7 per cent. silicon, and a little

nickel and chromium gave 14.5 tons/sq. in. in the cast condition and a Brinell of 220. After oil quenching from 850 degrees C. the tensile strength was only nine tons/sq. in. although the Brinell had risen to 420. On tempering at 350 degrees C., however, the tensile strength rose to 18 tons/sq. in. without affecting the Brinell and an iron was produced with obviously valuable properties.

The automobile industry is not alone in taking advantage of the heat treatment of cast iron, and guides, runners, and cams of machine tools are already being improved by this means.

Before passing to the two non-ferrous materials with which I propose to deal I will first of all comment briefly on the vexed question of machinability which in a weak moment I was persuaded to include in the scope of this paper. One or two apparently intelligent men have in the past posed as authorities on this subject until they were led quietly away in the care of their medical advisers. Most of us however approach it with diffidence and subsequently retire with a respectful apology. My comments therefore are simply those of an interested observer.

The outstanding difficulty in making use of published information on the machinability of various steels has always been the impossibility of correlating or reconciling the results obtained by different investigators. Different people have arrived at opposite conclusions and the opposite conclusions have apparently been equally well substantiated by the different tests. The reason for this of course has been the large number of variables in operation, and these variables are too well known to production engineers to require explanation by me. It is refreshing therefore to note the partial success at least of the U.S. Bureau of Standards in carrying out their comparative tests in such a manner that the machining performance of the different steels could be compared under exactly similar conditions. In the past few years they have published a large amount of valuable information, the so called machinability of a material being expressed in terms of the now familiar factor developed by Taylor, viz., the cutting speed at which a standard tool will last exactly twenty minutes. The work they have already done is far too vast for review in this paper but one or two points of interest may be noted. The results as expected, demonstrate the value of tensile strength (or the equivalent Brinell hardness) as an indication of the machinability of a particular material and for any one steel there is no question that its machinability bears a close relation to its Brinell figure. But they also demonstrate the weakness of the Brinell for these comparisons. I will quote only two examples taken from a large number. For rough cuts a low nickel steel will machine very much faster than a .44 per cent. carbon steel heat-treated to give the same Brinell figure whether that Brinell be just over 200 or just under 300, and in the high tensile range a chrome-molybdenum

steel is much easier to machine than a 3½ per cent. nickel steel of the same Brinell.

We did not of course, have to wait for the U.S. Bureau of Standards to show us that Brinell figures can be very misleading. The Brinell figure of a stainless steel gives little warning of the difficulty always encountered in machining it; the Brinell of one of those sulphur alloys marketed as "free cutting" steel is meaningless from the machining point of view; and some of the softest ferrous materials are a continual source of machining trouble.

The trouble with stainless steels of course is their amazing ability to work-harden and a very small amount of surface deformation is sufficient to increase the hardness locally to a surprising extent. I have been presented with a piece of stainless steel with the statement that it was unmachinable only to discover that a blunt tool had increased the surface hardness from 207 to 402. Of course foremen and machinemen are on the lookout for this trouble with stainless steel but many other alloy steels have work-hardening properties to an extent seldom appreciated. Quite recently I was asked to test a piece of 3½ per cent. nickel steel bar which had successfully resisted an attempt to turn an undercut. I inquired about the condition of the tool and was informed that the tool had already been suspected but when it was removed and a freshly ground one substituted no better result had been achieved. As a matter of fact investigation showed that the first tool *had* been blunt and had so hardened the surface with which it was in contact that the said surface had developed a Brinell of 444 and the new tool did not have a chance.

I mentioned also that some of the softest materials give great trouble. One of these is low-carbon case-hardening mild steel which frequently gives so much trouble by tearing that it is a matter of no small difficulty to compromise between machining speeds and quality of surface finish, and forming tools have a very thin time indeed. In this same connection malleable castings which are so often the object of wholesale scrapping for hard spots have occasionally provided me with proof of the fallacy of circumstantial evidence. I remember one batch of castings which were subjected to a milling operation. About 50 per cent. were laid aside as too hard to machine. Visual examination showed that the small areas which had been machined before abandoning the attempt were blue and glazed and certainly looked hard if metal ever did. In actual fact a Brinell test on these areas using a light load and a small ball gave a Brinell figure of well under a 100. In other words it was the softness and pliability of the pure iron skin of the annealed castings which was the cause of the trouble and an adjustment of the cut saw them all through successfully.

In investigations into these machining troubles the modern hardness testing machines are of great value to the investigator. With

machines like the Vickers pyramid diamond hardness testing machine and the Firth Hardometer it is now possible to obtain reliable Brinell figures representative of the local hardness of such small areas and such thin layers that the older and cruder methods are falling into disuse for this purpose and many interesting facts are being brought to light. The standard Brinell machine with its large ball and heavy load is useless for investigating the sort of troubles I have described and the scleroscope has too many limitations for such a purpose. The Rockwell instrument put America well in the lead in appreciating the significance of local effects in material being machined and it is very fortunate that we have now a selection of even more reliable instruments available.

One of the most important points already mentioned is the ability of these light load machines to give reliable figures for the skin hardness of steels. They have proved conclusively for example that low carbon steels whether alloyed with nickel or not can attain a skin hardness in water quenching which used to be regarded as theoretically impossible. They have also enabled production engineers to understand more clearly the effect of surface conditions in rendering good tools incapable of completing their job.

In the great mass-production shops of the U.S.A. and to a small extent in similar shops in this country, a systematic attempt is made to overcome the inherent machining troubles of their steels in various ways of which the most popular is suitable heat-treatment. The machinability of the steel very naturally depends on its heat-treated condition and the most suitable condition varies from operation to operation. The U.S.A. shops which have got this matter down to a fine art actually take account of this variation and as an example you will find them normalising low carbon mild steel for turning and milling and after these operations quenching the material from 900 degrees C. in order to prevent it from tearing in subsequent broaching and screwing. The advisability of such a system is a matter of economics and for small factories it is often out of the question. In bigger places it requires much experiment plus close co-operation between the metallurgist and the production engineer. In any case such a system obviously depends on the decision of the management whether material is to be purchased unheat-treated or in the finally heat-treated condition. If the latter then the physical properties will confrom to a more or less rigid specification and the production engineer will just have to do the best he can with his tools.

This question of specification raises another point. The modern tendency is towards standardisation of materials and in the compiling of standard specifications the question of machinability has so far been relegated to the background. That is unfortunate, but there are so many other factors requiring control and so many

other conditions requiring clear definition, that the future does not look too bright from the machining point of view. It is unfortunate too that in both carbon and alloy steels there is a fairly general rule that the better the quality from the point of view of physical properties and chemical composition the more difficult is the steel to machine. In carbon steels the lower the amount of impurities like sulphur and phosphorus the greater the machining difficulty and in the alloy range a tough steel with a high impact value is more difficult to cut than a less ductile steel with the same Brinell hardness and tensile strength.

Although many of the steels which find favour because of their free-cutting qualities have one or more important properties impaired as to the result of the additions to their chemical composition, there is no doubt that much can be done in this way. Good quality free-cutting mild steels are few and expensive. A really good case-hardening mild steel with free cutting qualities will cost between two and three times as much as good case-hardening steel without these qualities—but, of course, under certain production conditions it might well be worth the money.

Molybdenum is coming into its own as a constituent of alloy steels which renders them more easily machined and it has the additional advantage that because of its other valuable properties described earlier in the paper it makes possible the reduction of nickel and chromium contents to a more machinable range and yet attaining the same physical test results. I think I have now said enough on this thorny problem to stimulate a discussion from which I hope to learn more than you have learned from me.

I would like now to turn to the non-ferrous world and although it contains scores of materials as useful to the heavy industries as to the sanitary engineer and all well worthy of description, I propose to confine myself to two—namely, aluminium and bakelite.

As far as aluminium is concerned the chief features of recent development have been the increased strength and ductility of its alloys by alterations of chemical composition which in some cases are alone sufficient and in others require the assistance of heat-treatment. A notable feature of some of these heat-treatable alloys is their malleability when hot which enables them to be forged and wrought like steel with still further advantage in enhanced mechanical properties.

There is a literally inexhaustible supply of the ores of aluminium and with the strength/weight ratio of its alloys increasing by leaps and bounds there is little doubt that it is destined to be one of the main constructional materials of the future. However, it will probably have bakelite and its relatives as keen rivals for popularity.

When a new material begins to rank with metal, stone and wood as one of the four principal materials of construction it becomes a

subject for thoughtful consideration by engineers. Bakelite is the most important of the synthetic resin plastics and it is worth bearing in mind that in 1932 the aggregate value of the products of the plastics industry in the U.S.A. was more than one-eighth that of the products from the lumber and wood-working industries of that country. Yet the wood industry has been long established while the plastics industry might be considered as still in the industrial nursery.

For the heaviest duty in buildings and machines it would appear that these resinoids, as they are called, will not supplant metal. On the other hand, it is conservative to assume that for many less strenuous services they will replace metal entirely. The most important group, of which bakelite is the main member, is the phenol resinoid group. By the union under well defined conditions of two evil smelling and repulsive liquids there is formed a resin which is used as a binder for wood-flour, asbestos, etc., to form moulded materials and as a binder for fabric to make laminated materials. The finished product is resistant to most of the normal conditions of structural breakdown. It is characterised by a high degree of electrical and thermal insulation, it is impervious to water and other solvents, it resists corrosion and moderate heat, and it possesses a degree of toughness and strength unusual in organic substances. In the course of my remarks I have referred frequently to the importance of the strength/weight ratio of a material, and the following figures demonstrate the ability of bakelite to replace metal on a constructional and strength basis.

	Tensile strength tons sq. in.	Specific gravity	Specific strength
Alloy steel	60—100	7.85	7.6—12.7
Laminated bakelite...	10	1.35	7.4
Duralumin	18	2.75	6.5
Spruce	2.5	0.48	5.2
Mild steel	30	7.85	3.9

Figures for tensile strength and specific gravity are separately important, but for many applications in the automobile and aircraft industries it is the combination of the two which is the final test of merit and that combination is best expressed by dividing the tensile strength by the specific gravity. This gives the relative load carried for a given weight of the material, and may be called the specific strength. On this basis of comparison the laminated resinoid materials are second only to alloy steels. They are superior to aluminium alloys, mild steel, and wood to an extent which is not yet adequately appreciated by engineers.

In such materials we have, of course, to regard with equal care the property of shock resistance or impact strength. Now the average resinoid material in the early days of the plastics industry was relatively low in impact strength, but in recent months wonderful improvements have been effected in the U.S.A. which yield products whose shock resistance is 10 to 20 times greater than the best previous grades, and any idea that resinoid materials are necessarily brittle or fragile is erroneous. It is now possible to mould resinoid parts of fairly thin section which can be dropped 50 feet on to a concrete floor and suffer no fracture.

The history of man has been written round so-called ages named after the materials from which his handiwork has been largely fashioned, and we may now be entering the plastic era. The resinoid plastics are too often referred to as "substitutes." They are not substitutes in the poorer sense of the term. Substitution of that kind is as old as the days of Tubal-Cain, who tried to persuade his neighbours to use his iron tools to replace their stone and wooden ones. It probably took most of his fabled six hundred years of life to overcome their prejudice and sales-resistance.

(*The paper was followed by a film on bakelite.*)

Discussion.

MR. KIRKWOOD : I think Mr. Macdonald has done us a very great service in emphasising that the materials which production engineers usually think of are not nearly so limited as some of us have imagined. The use of resinoid material is somewhat strange to most of us, and from what he has shown us, we will have to know more about it in future. I think the film and his remarks have shown that we have got to learn how to utilise this material to its best advantage. In connection with machinability and lack of specifications calling for a proper machinability value, I would like to ask Mr. Macdonald if he has any views on the specification, which I now believe is called for by the armament people for rifle bore material. I remember a lecture given last year, I think, in which some very extensive experiments were dealt with which had been carried out by the Royal Arsenal in qualities of material suitable for making rifle barrels, and they found out that certain steels gave satisfactory results and certain steels did not. They went to very considerable pains to get these two different types of steels separated. They found out that the macrostructure, or the form of the flow line, if I may say so, had a considerable effect on machining, and they now specify, in addition to the ordinary physical tests, that the steels submitted must pass a test of machining, viz. : They must be able to be drilled at standard feed and speed and give a satisfactory finish, otherwise they will not accept the consignment. I think that this type of specification could be developed. It would be of considerable assistance to production engineers.

MR. MACDONALD : I was very interested in Mr. Kirkwood's remarks with particular reference to this question of machinability of steel being, to a certain extent, dependent upon its macrostructure. The particular investigation to which he refers deals with the boring of rifle barrels. However, the investigators were able to say that similar results could be achieved in turning and these results were certainly amazing. What they regarded as an unsatisfactory bore had what seemed to me a good finish and the satisfactory ones were simply astonishing in their opalescent gloss. They attained these results by special control of the steel early in its production. Actually in the casting of the ingot. A good result was obtained in conjunction with a macrostructure which showed that the fibres of the steel were coarse. Now, both in fractures and micro-sections, a steel which has been rolled in the form of bar has a definite fibrous structure. By increasing the coarseness of these fibres and keeping them continuous they could obtain this wonderful finish with the greatest of ease. The tools worked easily. On the other hand, in

very many respects it would be dangerous to widen the scope of this particular type of free-cutting and fine finish material. The reason being that these coarse fibres are usually found in conjunction with material which has certain unsatisfactory characteristics. You are all aware that most of the physical property figures from bar and small forged material is taken with the test pieces longitudinal. For many applications, however, a physical property test of the same material in a direction transverse to the flow lines is of considerable importance, and in these particular steels with the coarse fibres, these transverse physical properties are definitely unsatisfactory. Indirect proof of that is obtained by these people finding it impossible to get similar results with austenitic steels, and these give rather wonderful physical properties when taken in a transverse direction. In other words, the greater difficulty is found with the steel which gives the best physical properties in the transverse direction. I therefore feel that with certain bar applications much can be done on this lines, but in many applications, where the transverse properties are of some importance, I suggest we shall have to go very warily indeed.

MR. BUCHANAN : Enumerating the factors governing the choice of material, it might be suggested that the method of manufacture is of sufficient importance to be considered as a special item. While some components are of such a nature that the method of production is obvious (e.g. steam cylinder or condenser tube), there are others which can be produced by a wide variety of methods and the method of production controls to a certain degree the materials which can be employed. Mr. Macdonald has given a lucid explanation of the need for and the value of alloy steels. Among other things, he called attention to the effect of size on the properties obtainable and pointed out that the B.S.I. figures are all taken from 1½-in. diameter bars. In this connection it might be mentioned that there is much valuable information on the effect of size in the *Automobile Steel Research Report*, 1920, and also in a N.P.L. paper published in 1926. The International Nickel Company have recently issued a simple chart showing what steels to use and what heat treatment to give them in order to obtain varying degrees of strength on different sizes of bars. The range covers from 1-in. to 12-in. diameter and in terms of yield point from 25 to nearly 80 tons per sq. in.

In speaking of malleable cast iron, Mr. Macdonald pointed out the necessity for careful control but also mentioned the assistance of Providence, in this case, however, it is surely an example of—Heaven helps those who help themselves. The history of malleable cast iron in America has shown that it has a distinct and quite important place in engineering, since it possesses the ductility which cast iron lacks, yet is easier to cast than steel.

The other remarks on heat resisting cast iron are of special interest because Nimol was first developed at Cathcart—it might be added that Nimol has also very good resistance to a variety of corrosive conditions and is the nearest approach to a corrosion resistant cast iron which is available in a machinable form to-day. The heat treatment of cast iron to which reference was made is still doubtless in its infancy. Already in some branches of power engineering it has been applied with successful results in the reduction of wear. When speaking of the prospect of machining in the future, Mr. Macdonald was surely unduly pessimistic; already the "Widia" type of tool has completely altered the outlook in some directions and we may be sure that the metallurgy of this type of tool will advance at least parallel with improvements in materials to be machined. In speaking of non-ferrous metals the paper has dealt mainly with aluminium alloys but it might be mentioned that very striking developments have taken place in other non-ferrous groups. We have now alloys which can be hardened and softened by heat treatment, cast alloys giving over 50 tons per sq. in., some giving over 60 tons in the worked and heat treated condition, and some giving over 300 Brinell.

Towards the end of the paper, there was an enthusiastic reference to the plastics industry. While concurring in much that was said it must be pointed out that materials like bakelite are produced by the simultaneous application of heat and pressure in a die and hence, generally speaking, are not suitable for the production of small quantities. In the table of strengths and weights, the figure for duralumin appears to be rather low; one expects at least 25 tons per sq. in. from rolled or forged light alloys like duralumin, on this basis the specific strength would be nine, which would place it second only to the best of alloy steels. The whole paper is stimulating of thought and its breadth of outlook is useful in these days when one is apt to be snowed under by multiplicity of details.

MR. MACDONALD: Mr. Buchanan has said a great deal which does not call for a reply. With regard to the question of method of manufacture being of sufficient importance to be considered as a special item, I would, however, draw his attention to the fact that the method of manufacture is usually a question of economics. It is closely allied to the cost of manufacture and I have given cost of manufacture a place to itself. Malleable cast iron: I can only say that Heaven may help those who help themselves, but Heaven would need to help those whose lives depended upon some of the malleable cast iron it has been my misfortune to test.

Tools: The situation in the past few years has altered wonderfully with the availability of cutting alloys like "Widia." That substantiates my pessimism to the future because we are evidently dependent upon the improvement of the cutting qualities of tools

to overcome difficult machinability and we are doing very little in the way of standardising easily machinable steels.

Bakelite : His remarks have definite point. I would point out, however, in regard to the figure 18 tons per sq. in. for duralumin that you only expect well over 20 tons per sq. in. for duralumin in certain forms, and these forms are forms in which bakelite is not available at the present time. I compared it with bakelite in similar forms.

MR. R. J. TAYLOR : I wish to devote myself to the cast iron question. There is no doubt, as he has said, cast iron is one of the things which has developed recently more perhaps than any other element or material. I was going to ask him if he had had any experience of cast iron melted in electric furnaces. I understand in 1933 the *Electric World* in America issued a lot of data on that, and to-day there is a motor car firm, and a large one, in America who have cast iron crankshafts running at the present time in automobiles. I think that that alone shows how cast iron has advanced in its use. They are also using cast iron for camshafts very satisfactorily. With reference to malleable iron, it is quite true that all the malleable iron I have seen has been described not all bad. I understand that the material is melted in electric furnaces and goes through four heat treatments, and this is giving very good results.

MR. MACDONALD : As far as electric furnace irons are concerned the many advantages in wonderful control obtainable over their chemical composition affects their physical properties as cast. I would suggest, however, that although the better physical properties resulting from such control has increased the use of cast iron in certain directions it has only been partially responsible for the use of cast iron in certain American crankshafts. That is more a question of design. I would suggest, in fact, that if the matter were put into the hands of the automobile design office many such alterations could be made in this country at the present time. Its use for camshafts has been largely the result of the ease with which cast iron can now be chilled to greater hardnesses than previously obtainable. I am glad he at least agrees with my remarks about malleable castings. I agree that certain recently patented processes have, according to the advertisement matter issued by the firms concerned, apparently given rather wonderful properties, but I would like a little more experience of them before giving a final decision.

MR. EAGLESHAM : I have for many years been using the product of rolling mills and foundries, and not a little of my time has been spent in listening to metallurgists. I have often wondered what accounts for the big differences which occur between the products of these institutions and the exact information recorded by the metallurgists. We get exact readings of test material, but in the

shop the product is so irregular we feel there is a wide gap between the practical side and the scientific side. Can Mr. Macdonald explain this ?

MR. MACDONALD : I can only suggest that Mr. Eaglesham cannot be so certain about the careful control of the products as he says he is. In other words, if the chemical composition of the cast material is carefully controlled, if the rolling heats and heat treatments are carefully controlled—I would suggest that the source of trouble is a mystery.

MR. EAGLESHAM : I said the specification is definitely stated.

MR. MACDONALD : Well, Mr. Chairman, I would suggest it is rather difficult for me at this distance to say where the error lies when there are so many variables. If the chemical composition is not carefully controlled, if the rolling temperatures are not carefully controlled, if the heat treatment furnaces—if a whole lot of other things—it is not surprising that there are irregularities occurring. It is impossible for me to be any more definite than that.

MR. R. TAYLOR : Mr. Macdonald referred to cast steel and showed that the addition of nickel generally made the casting better and also helped in machining. Also with silicon, after you passed a certain point it helped machining. I know a case of stainless steel, and we found it was very irregular all over and no amount of treatment would make it different. That was stainless steel, cast with nickel and silicon in it.

MR. MACDONALD : I would suggest that there is perhaps a little misapprehension here. I cannot recollect saying that the addition of nickel to cast steel improved machinability. I would suggest that the steel as cast, rather than in the heat-treated condition, is a shade more difficult. In the heat-treated condition you can almost take a line corresponding with wrought steels. In view of the normal difficulties with stainless steels I am not surprised my questioner has indicated his experience of very considerable difficulty. Neither do I recollect saying that the addition of silicon improved the machining qualities. I have no information whatever of the effect of the addition of silicon to cast steel. As far as cast iron is concerned it varies considerably. I pointed out that when it was added to cast iron it increased growth and in the beginning it made it easier to machine. I indicated also that beyond a certain percentage it retarded growth. Its effect at that stage on machinability was slight.

MR. PLATT : Would Mr. Macdonald tell us whether it is possible for metallurgists, as metallurgists, to define exactly whether material, particularly mild steel, is machinable as you receive the part ? Can he say whether that part is easily machinable or whether it is like a lot of other things—would you have to try it in the machine first ? Can he tell definitely from analysis of the casting or of a

part whether that casting is suitable for its particular purpose—better than the man in the shop can with his magnifying glass? On the second slide Mr. Macdonald gave a figure for three per cent. nickel of 52 tons tensile with 100 foot pounds Izod. How did he obtain that result?

MR. MACDONALD: The first portion of his question: to deal with it properly it would occupy the rest of the night. I would suggest, however, it is definitely an important question, viz.: Can you tell from your laboratory tests whether steel is going to be easily machinable or not? Within limits you can. But these limits are pretty tight. If you send a piece of mild steel bar to the laboratory they have it analysed and have a tensile test taken of it, and you can decide from the analysis first of all if it has free cutting qualities; also if the impurities are so low it is likely to give difficulty in machining. I might mention the lower the sulphur and phosphorous impurities the more difficult it is to machine. You can get a rough idea from your laboratory analysis if this particular specimen has any free cutting qualities. You can tell from the tensile test what sort of condition it is in, and once again, you can tell from experience whether it is going to be easily machined or not. Beyond that you can tell nothing. The only test of any real value is the test in the machine shop. "Can you tell if a particular casting is suitable for a particular purpose or not?" Well, you can tell, for example, from the analysis of some of these austenitic cast irons that they have certain corrosive and heat-resisting possibilities. If he is referring to grey cast iron, you can tell far more from the condition in the shop. As far as grey cast iron is concerned its physical properties are far more important than its chemical composition. In 75 to 80 per cent. of its applications, buyers should specify physical properties and physical properties only, and leave the chemical composition to the foundry.

The figures for three per cent. nickel steel—52 tons tensile with 100 foot pounds Izod. Both the bars shown were similar in every way except for the nickel content. The small diameter of the bar was largely the secret of the wonderful impact test—viz., $\frac{3}{4}$-in. dia. As far as heat treatment is concerned the three per cent. nickel steel was quenched from 840 degrees C. and tempered at 620 degrees C.

MR. WRIGHT (Chairman): To the best of my knowledge no success has been achieved with moulding bakelite on to a cast iron shell, but I will make inquiries. The only success I know of is in applying bakelite varnish to a cast iron shell, and subsequently subjecting it to a polymerising process. That coating is very thin.

In connection with bakelite. Whilst bakelite is commonly used to give a certain finish and to reduce weight in many cases it is necessary to have weight and finish combined, I

would like to know if Mr. Macdonald can tell us whether it is possible to mould bakelite on a cast iron shell, and thereby get the dual result. Would it adhere to the cast iron shell?

With regard to the paper, I think there is plenty of evidence that Mr. Macdonald is fully conversant with the subject upon which he has been talking.

With reference to machinability, we will accept his apology for having included that subject in a weak moment. As machinemen we often regret that nickel steels ever developed beyond the prehistoric uses referred to. I think that Mr. Macdonald has only confirmed that the metallurgist does very little to assist us in our machining difficulties. Speaking from experience: when the laboratory people are asked to give an explanation regarding a failure, in their opinion the part is either made from bad material or is badly machined, and with damnable persistence they add: "probably the latter." I think it still remains with the production engineer to make the most of the information available. In the same thorough manner that Mr. Macdonald has surveyed the latest engineering materials, we must survey the field in which these materials may be used to advantage.

INAUGURAL MEETING OF THE WESTERN SECTION.

THE Inaugural Meeting of the Western Section of the Institution was held at the Grand Hotel, Bristol, on Wednesday, 15th November, 1933, at 7-30 p.m., Sir Alfred Herbert, K.B.E., Past-President, in the chair. The attendance numbered over 150.

Mr. J. T. Kenworthy, Hon. Secretary, announced the receipt of a large number of letters and telegrams sending greetings to the new Section and wishing it a successful future.

SIR ALFRED HERBERT: I appreciate very sincerely the honour you have done me in inviting me to take the chair here to-night at the inauguration of what I hope and believe will be a very important section of the Institution of Production Engineers, and I have to thank you for bringing me to Bristol because I have, during the day, had the privilege of meeting a good many old friends, and I hope of making some new ones, and I have also spent a very interesting time in two of your very important local works where I have seen much in very advanced engineering, and where I hope, I have learnt a great deal which will be useful to me later.

I think Bristol is ripe for the formation of this Section. Not only is it a big and important engineering centre, but those who are connected with its engineering industries possess initiative, take very great interest in their work, and have progressive minds, otherwise we should not have seen this very good gathering at our first attempt to launch this Section.

I am not going to take words out of Mr. Whitehead's mouth, but it a remarkable institution with which we are connected. It has made progress which I think is unexampled in the history of any institution of its kind. I think that the Institution is extremely fortunate in its choice of a General Secretary who combines extraordinary energy with great tactfulness and efficiency. He has been kind enough to give me certain figures. I don't want to bore you with statistics, but I should like to give you a few figures which show the progress of the Institution. In 1929 we had 21 lectures and three local sections. I will not give you the intermediate figures, but this session we have 76 lectures and 11 local sections. Now that is an excellent record of progress.

The day has gone by when we used to have secrets. Thirty or forty years ago if you knocked at the door of an engineering shop somebody looked at you with a very cold and freezing look. I remember as a very young and I think, not unenterprising man,

going over to Paris in the early days of the automobile industry and knocking at the doors of the Panhard-Levassoir works, and asking whether I could look round. I was received with a very stony stare and told that this was quite impossible. Now to-day I do not believe there is one engineering workshop in Europe or America which would receive me in this way, and I am very sure this is what we should be, open, free, and friendly with each other. Freedom in the interchange of information and friendliness generally has been of the utmost help to the progress of the engineering industry throughout the world, and this Institution of Production Engineers adds to that form of interchange of experience and information which builds up that great asset of business friendship.

MR. WHITEHEAD: In accepting the office of President of the Western Section of the Institution of Production Engineers, I feel it my duty to return thanks to you for the great honour you have conferred on me. I am proud to be the first President of this Section. Our Institution, of which I have been a member for ten years, is gaining strength, and being recognised as filling a long felt want amongst technical institutions. Your enthusiasm in getting the Western Section inaugurated is most encouraging, and speaks well for the future strength of the Institution. We have a large area to cover in a district with many diversified industries, and I trust that my fellow-members of the Western Section will work diligently to attract production engineers of the right calibre, and to assist in making our lectures attractive, so that members and visitors will leave such meetings feeling that we are what we profess to be—a body of responsible executive engineers interested in the science of production.

The Institution, although its headquarters are in London, is run on very democratic lines. Each Section has its say in the management or control. From the moment it was first suggested to form a section for this district we have had every assistance from the Council and other members of the Institution, and I am sure we can look forward to their continued help in making the Western Section as strong as any other section, but we must also do our share. I promise you my wholehearted support.

There are, as you know, many varied industries in the West of England, some of which are outside the ordinary run of engineering as it is commonly understood. I have had occasion to visit firms within a few miles of this room, and I have been impressed with the various interesting and ingenious machines being tried out. The production problems of some of them would make very interesting papers. I will mention two unusual machines being produced locally. One is an egg grading machine in which eggs are automatically graded according to weight, etc., and another is a machine which will pluck a chicken as clean as I generally shave, and I think,

with fewer gashes to show at the final viewing operation ! There are other machines just as ingenious and if we can only get some of the management and production engineers to join our Institution, become really enthusiastic and read papers, then I am confident that the services of the lecturers of the Western Section will be in demand from other sections and will be the means of putting our Section on the map.

I do most heartily thank you all for your support, and especially do we appreciate the honour bestowed upon us at this Inaugural Meeting by Sir Alfred Herbert, who has favoured us with the opening of our Section. I must confess that the work ahead is a little new to me, and just at present I rather feel like the Irishman who, when asked to explain the difference between a collision and an explosion, got over the difficulty by saying, " In a collision we know where we are, but in an explosion, where are we ? " I now have great pleasure in formally proposing the inauguration of the Western Section of the Institution of Production Engineers.

MAJOR NEVATT (Past-President, Institution of Automobile Engineers) : I have great pleasure in seconding the resolution. I feel a little diffident in trying to speak before such masters of oratory, in fact I feel I have no right to speak at all because I am not a " production engineer." It is true that I have filled in a form giving details of my credentials and of my " sticky past," and I hope that I shall be granted membership, but at present I am not a " production engineer," but hope to be one.

I am just asking myself a thing I very often ask other people, that is : Why join an institution ? I feel, as an engineer, institutions make one acquire more dignity and importance, personally I feel that is why one ought to join an institution. I don't know that they make us any cleverer, but they do lend dignity to our profession. They also give us an exchange of thought, which keeps us from getting into a rut intellectually.

There are a lot of institutions, but I do feel that the Institution of Production Engineers is going to rank very soon with any of the senior institutions, and if I might say a word to some of the younger men, I should say come in while the going is good, because I feel that very soon the Institution of Production Engineers will be as difficult to enter as any of the senior institutions.

During my term of office with one of our senior institutions I may say that nearly 75 per cent. of our applicants for membership were turned down, and they were turned down mostly through want of education, and if I might speak to the younger people I would say you must concentrate now on your night schools and be prepared to be put through a very stiff examination for entrance to

an institution, not only this one, but for some of the senior ones to which you ought to belong.

I have pleasure in seconding the resolution.

MR. S. CARLTON SMITH (Chairman of Council): It gives me great pleasure to support this resolution. During the past two years it has been my job to go round every one of our 11 sections, as far apart as Glasgow and London, and now Bristol, and the progress made is wonderful. Ours is a great institution and I am sure Bristol is going to be a very great centre. It is the enthusiasm of every member, as well as that of your President, Secretary, and Committee, which will ensure success. In wishing you success I feel this is already an achieved fact.

Although Rudyard Kipling wrote: "East is east and west is west, and never the twain shall meet," it is a happy augury in the progress of our Institution when we are rapidly dotting the map with new sections, that the first President of the Eastern Counties Section is giving his paper at your Inaugural Meeting in the Western Section, and that the first President of the Western Section is going next week to the Eastern Counties Section, where the next Council Meeting is to be held.

MR. J. D. SCAIFE (Member of Council and Past-President): I have come down here from Yorkshire to join in the pleasure of this Inaugural meeting, not to suffer the anguish of speaking. Frankly, speaking does not come very easy to me, I am more at home in the shop, but I should like to say how pleased I feel, as a member of Council, that Sir Alfred Herbert came here to "launch this ship" or rather this section of the Institution. We know that Sir Alfred Herbert represents, in this country, the very high water mark of production engineering, not only in himself but in the vast organisation of which he is the head. I also want to say how pleased I am to realise you have got such a man as Mr. Whitehead as your first President at this section. I have been acquainted with Mr. Whitehead for many years. We became first acquainted during the war, when we were associated in the manufacture of aero engines. I don't know many others in your area, but I can say for certain you have got a splendid man in Mr. Whitehead for his job.

The resolution was put to the meeting and carried with acclamation, after which the Chairman called on Mr. F. Ayton to read his paper on "Instilling Machine Shop Sense in the Drawing Office."

At the conclusion of the discussion on Mr. Ayton's paper, MR. FEDDEN proposed a vote of thanks to Sir Alfred Herbert for presiding. They had been very fortunate to have Sir Alfred Herbert in the chair at this Inaugural Meeting. The members of the Institution knew the work Sir Alfred had done during his two years as President and the practical and invaluable help he had given.

SIR ALFRED HERBERT: I appreciate most sincerely the kind vote

of thanks which Mr. Fedden has moved and you have so generously and kindly received. I have had a most interesting day, everybody has been very kind and I hope I have learned something. I am confident from what I have heard at this meeting, from the keenness, intelligence, and interest which everyone has shown, from that " clash of flint and steel " in the discussion, that you have the right stuff here, and I want to take this opportunity of saying that if later on you feel you would care to come to Coventry—and in these days of rapid transport that is not so very far—and have lunch with me, I think I could find a few things which would interest you.

INSTILLING MACHINE SHOP SENSE IN THE DRAWING OFFICE.

Paper presented to the Institution, Western Section and Eastern Counties Section, by F. Ayton, M.I.E.E., M.I.P.E.

IT is only those who were in responsible positions in engineering manufacturing in the pre-war days who can realise the great difference between the conditions of carrying on a business in those comparatively easy and comfortable times and those which exist to-day. In those now seemingly far-off times a firm was often able to keep a model in production for years without change and yet manage to maintain a satisfactory demand. In these post-war days, however, we are all striving to out-distance one another, to get the better of our competitors by frequently changing our designs with the aim of securing talking points the other fellows do not possess.

Change and Competition.

Thus we have constant change, and all the time a striving to lower cost of production in order to maintain our places in the world's markets—a fight against most difficult conditions when the competition is with foreign products manufactured in countries where the workpeople are either content with or forced to put up with a much lower standard of living than exists in this country, and consequently are paid appreciably lower rates of wage.

But in spite of all our difficulties and our handicaps, it can hardly be gainsaid that British engineers have made headway in world trade and that there are portents which justify us taking a reasonably optimistic view of the future of our industry. In viewing the present position and prospects one may gain inspiration from those lines of Kipling's in the poem story "The Mary Gloster" where the erstwhile sea captain, become a wealthy shipowner, looking back from his death bed on those years of striving and hard work which eventually led to fortune, says :

> "And they asked me how I did it and I gave them the Scripture text, 'You keep your light so burning a little in front o' the next!'"

That in effect is what every alive engineering firm is striving to do—to keep its light so burning a little ahead of the rest—at any rate that should be the aim. And an important factor in the realisation of that aim lies in making the right thing in the right way

Bristol, 15th November, 1933; Ipswich, 6th March, 1934.

and marketing it at the right price, and the latter is obviously the figure which will secure adequate sales.

In the pre-war days the price of a piece of machinery was not always the determining factor in the purchaser's choice. Quality was often the major consideration, and on quality the British engineering firm could, as a rule, hold its own against the foreign make. To-day, however, with a world impoverished in the first place by the effects of the war and further impoverished by the subsequent years of depression and political disturbance, price has more often than not become the major consideration in determining the purchaser's choice. Hence the need for constant attention to everything that bears upon the cost of manufacture.

We must not, however, forget that in marketing any piece of machinery appearance counts for something and that the first impression made upon a prospective purchaser by its appearance, nice or otherwise, may largely influence his ultimate choice. Nice appearance, as well as good external finish, does convey the impression of quality and efficiency and, generally speaking, these features may be incorporated without affecting the design from the points of view of efficient functioning and economical manufacturing cost. Good appearance, when applied to a piece of machinery, is a term somewhat difficult to define—a perhaps not inapt way of describing it is cleanness and harmony of design. Not infrequently one sees a machine which, in its general appearance, gives the impression that the designer, through lack of the power of imagination, had been unable to form a mental conception of what the machine, as a whole, should look like, and having drawn out something as the heart of the mechanism, as afterthoughts, spatchcocked all manner of odds and ends around it.

Cost largely Governed by Design.

Cost of production is to some extent governed by design. A design may be such that the machine made in accordance with it will function perfectly well and efficiently or, in other words, will give the desired working results, yet be so costly to produce as to be practically unsaleable. Hence the obvious necessity in designing to consider not only the efficient functioning of the machine and the matter of appearance, but also the design of each detail for the lowest possible cost of manufacture. It is not incorrect to say that in most instances there is more than one way of designing any particular part, each of which will prove quite satisfactory so far as the efficient working of the machine is concerned, but one of them will be the cheapest to make. It is the obvious duty of the designer to find that particular way of designing the part.

Now the designer may be quite capable of designing an excellent machine so far as its working is concerned, but it is not always the

case that he has that detailed knowledge of works production methods which will enable him to design the machine and its parts in such a way that it may be made at the lowest possible manufacturing cost. The ideal, of course, would be that every designer draughtsman should, in the course of serving his time, have received a practical training in each production department of the works, including forge, foundry, and pattern shop. This comprehensive training, although very desirable for every engineer, would seem hardly possible for the average man who goes into the drawing office. But if this standard of training were practicable for the draughtsman, it cannot be said that it would ensure that, when he reached the stage of promotion to the task of designing, he would be able to design for the lowest cost of production, the simple reason being that methods of production are constantly changing and undergoing improvement, besides which one has to bear in mind that the man may be engaged in a drawing office of a different works to that in which he served his apprenticeship, and it is well known that production methods differ as between one factory and another. One also has to recognise that draughtsman, like the rest of us, differ from one another in their particular characteristics. One may be good mathematically, another may have as his attribute a good eye for nice appearance and symmetry in design, another his ingenuity in devising mechanical movements of a special kind, and so on. It is, however, rare to find one who allies to other necessary qualifications a real understanding of design in relation to economical production, and the firm possessing such a man may be deemed fortunate.

How ever efficient the shop staffs may be in getting work done well and at low cost, and however up-to-date the plant may be, the cost of production will be largely governed by what is done in the drawing office.

Importance of the Foundry.

What can be done in lowering the cost of manufacture by a comparatively small alteration in the design of a particular part is sometimes rather astonishing. The alteration has no effect on the working of the machine, yet it is something which makes for important saving of cost in some one or more of the manufacturing operations. It may be that a casting has been so designed that, although quantity output is required, it cannot be put on to a moulding machine. There is a host of ways by which the draughtsman, quite unconsciously, may, in the details of designing, make it difficult for the foundry to ensure the production of good and sound castings, as well as castings at reasonable cost. We ought always to bear in mind the importance of the foundry in engineering production ; it is, as it were, the root of the production tree and if

anything goes wrong with the root it affects the whole tree. When I speak of the foundry, I refer, of course, to foundries producing both steel and iron castings, as also those of the non-ferrous types. Usually a defect in a casting is not revealed until it has progressed well through the machining operations, with the result that all expenditure on manufacture up to that stage is irretrievably lost. I hold, therefore, that no trouble taken can be too great to see that the design laid out on the drawing board is such as will enable the foundry to produce with a reasonable degree of certainty a sound casting at reasonable cost, and at the same time one that lends itself to ease of handling in the manufacturing operations to follow.

A direction in which sufficient consideration is not always given in the drawing office, particularly in the design of castings, is provision for facilitating chucking, holding in jigs or on to machine beds. This has, as a rule, an important bearing on cost of production.

Another matter not concerned with production methods, but in connection with which the drawing office, by care and thought, can do something useful and important when preparing new designs, is by so designing that as far as possible materials and bought goods, such as bar and section stock, bolts, nuts, screws, key material, lubricators, etc., required, shall be what are already kept in store or in general use in the works. It should always be impressed on the designers that to bring in a new size where a stock size, by a slight modification of the design, could be used, is to lock up capital unnecessarily. Then again, the designers should be required to use, wherever possible, existing patterns or dies if such can be worked in satisfactorily.

These are but a few of many illustrations which could be given to illustrate the problem I am dealing with, which is " Instilling the Machine Shop Sense in the Drawing Office." I think that possibly it would have been better had I entitled it : " Instilling the Production Idea in the Drawing Office," because it covers, of course, the whole range of manufacturing operations. I am not intending to cast any reflection on draughtsmen. I have, in my younger days, worked in a drawing office and appreciate the draughtsmen's difficulties and I have already referred to them. I venture to put it to you that there is only one way of avoiding the difficulties I have mentioned, that is to say, designs made without consideration for shop requirements for economical production, and it is to bring what I term " the machine shop sense " into the drawing office by arranging for the fullest and closest possible co-operation between the designing staff and the works' production staff, and insisting upon it. This is the system which for a long time has been in successful operation in the works with which I am connected, and it works extremely well ; doubtless we are not the only people who work things in this way.

Co-operation.

In brief, the system covers co-operation from the initial stages of designing to the point when the finally approved model is put into production. The designer is required, as he progresses with the preparation of a design, to consult with the different shop people as to the suitability of the proposed designs of the individual parts for low cost of production. For example, the foundry manager is consulted as to designs of castings, from the point of view of production in the foundry, the foreman patternmaker also coming into consultation in such a matter. The machine shop staff are consulted in regard to facilities provided for machining and the elimination of unnecessary machining; the matter of design of forgings and pressings is gone into with the respective heads of these departments, and so on. The buying department is often, with advantage, consulted in regard to the relative cost of different materials.

When the design has been completed, if it is an important one, a conference takes place between the production people and the head of the drawing office, together with the draughtsmen responsible for the design, when the drawings are, as it were, finally vetted. If it is then found that saving can be made in cost of manufacture by any alteration in design, such alteration, if it will not affect the satisfactory working of the machine, is decided on. Usually when it is a question of establishing a selling line in any particular machine, the next step will be to build a trial machine by hand, as it were—in other words, without jigs and special tools such as would be employed for quantity production. The foremen concerned are required, during the building of this trial machine, to keep notes of any difficulties which may be experienced due to design, as also any ideas which may occur to any of them for alterations which would reduce the cost of manufacture. Then, should the trial machine have satisfactorily passed all tests applied to it, and a decision made to put it into regular production, another conference takes place over the drawings and the notes referred to are taken into consideration. As a result it is usually the case that further alterations are found to be advantageous.

It may be urged that such procedure takes up a good deal of the time of the shop executives. It may do, but the results are well worth while since it is a very costly matter to find out and make changes in design once jigs and special tools have been made.

As a rule the sales department will have decided what the maximum factory cost must be which will build up into the selling price which they deem will secure a market for the particular machine. Consequently, the design when completed will need to be placed

into the hands of the cost estimating department in order to ascertain whether it can be made for the figure laid down, and this is done before even a trial machine is put in hand.

Discussion.

SIR ALFRED HERBERT (Chairman): This is a very excellent paper and I am sure everyone found it very instructive. On listening to it I am struck with one very important fact. This Institution of Production Engineers is entirely composed of practical people and that paper is written by a practical man on a practical subject, and therefore appeals to us all very strongly.

MR. WHITEHEAD: When we chose the subject of the paper for to-night it appealed to both the Committee and myself as being one you can argue on from either side, and I hope that some of you will stand and fight it out on both the design side and the production side.

I am very strongly on the side of the designer. I think that the designer should certainly serve his time in the shops and grade through to the drawing office, and it is as such that I am looking at him now. As a draughtsman he should be thoroughly *au fait* with tolerances, etc., but he cannot be a brilliant shopman and designer. I think the opportunities of the future depend on the brilliant designer and that he should not be handicapped. You should let him go " the whole hog " and produce his designs. There are small points such as Mr. Ayton raised, on the design of castings or things like that, where assistance from the shops may be needed, but I think the designer should have first and last say. If the foremen, chargehands, and the buyers come into it, you will find the attitude creeping in of " rather than take a bit of trouble let's stay where we are " and that you won't make progress. Let the design side put up what problems they like; they are responsible. They put their brains behind it and I don't think they should be handicapped. My opinion for what it is worth is, that you can make anything as a practical job provided you split it up into simple operations. Take a very complicated mechanism like a maxim gun. When you see the drawings of that they look most formidable but they will boil down to a series of simple operations. I have been round the Small Arms Factory, and you can take any of the rifles in production to-day and these complicated pieces of mechanism are reduced to simple operations that can be done by any boy or girl in cases of emergency, and I think we have got to support the design side by taking that point of view. By all means confer with them on the question of limits, etc. If the designer starts the job and he can feel he has a perfectly free hand and that the production people will back up his designs, that is the only way we can progress.

MAJOR NEVATT: I am in great sympathy with Mr. Ayton because he is trying to look at both sides of the question, but I am a

bit at variance with Mr. Whitehead, because I have never yet found a design that could be made ! Speaking for the automobile industry, I feel that nothing can be left entirely in the hands of the designer. If you do, you will never get a vehicle on the road.

My own experience is that good design people will produce good work, but no designer is able to see into the mind of the machine shop man. Get out the design, put it before the machine shop and jig and tool people ; further than that, you have got to put it before the erector. I am in the fortunate position of being my own customer and I can get the experience of the customer, and I never feel a design is complete, until, not all but some of the jigs are made, and one or two samples have been actually made and run on the road. I find that you must have co-operation between the whole of the people concerned. No matter how good your designer may be he cannot get into the minds of the machine shop and jig and tool men and the foreman erector or actual user. We have all got to co-operate in order to work with some measure of success.

MR. L. J. KAYE : I have worked both in the shops and in the drawing office and I find that as a rule it is most difficult to get two men to agree on the limits and tolerances which can be accepted for running fits. They diverge considerably in their opinions.

I feel that you have in this Western Section a wonderful opportunity of getting together to exchange ideas. It has been a fetish amongst some of the older type of British engineers to keep any special knowledge they possess to themselves and not exchange their views with the next man. I claim that this attitude is entirely wrong.

I have had considerable experience in visiting foreign firms on the Continent and I have generally found them more adaptable that we are in the exchange of ideas.

Mr. Ayton mentioned a firm who, when the design has been prepared, invite discussion between the works and drawing office. I am afraid this procedure is rare in England, but on the Continent it is often done.

I hope that when any of you get an opportunity of going abroad, either on holiday or on business, that you will spare at least a day or two of your time visiting Continental firms. I am sure that you will learn quite a lot. You will agree with me that we do not know all there is to know about engineering in this country and that on the Continent, the fact that they are foreigners does not mean that they do not know much. I assure you that foreign engineers are go-ahead, capable men and fully alive to all methods which can be adopted for increasing production.

MR. TURNER : With regard to the drawing office and works not co-operating, I think one could find a lot of firms where the works staff do not know where the drawing office is, and everybody has

different views on how a job should be done. This sort of thing is bound to lead to trouble, as it is too late to try and put things right when a job is finished and everybody finds it is no good. Cases of this sort could be avoided by co-operation between the different branches, and I think our meetings here should assist in obtaining this co-operation. The most important thing seems to me to be for the works and drawing office to get together when a job is in its infancy.

MR. TAYLOR : It seems to me that there is a difference in firms which work on mass production or batch production. This is rather an important point. There are cases in my trade—printing—where we can manufacture successfully in quantities running into millions per week, work that in small batches is completely impossible. We frequently find that on small jobs our artists have set us impossibilities, though we could mass produce the same work well anough. Has Mr. Ayton considered this ?

MAJOR HELPS : I am afraid I must cross swords with the speaker on one point. He has stressed " low first costs and building down to a price." The lowest possible cost may influence the untrained eye, but I would emphatically say I consider it a dangerous policy. I consider " building up to a standard " even more important. In time it becomes a case of the " survival of the fittest." The policy of building down to a price does not give reliability and the firm which practises it will not survive. For the last ten years I have been employed as maintenance engineer by an important docks authority and have had a great deal to do with the accepting of various designs of machinery and checking of contractors' proposed designs. I consider as a result of my experience that the modern policy of building down to a price may show lower first cost of the production, but this gain will be more than offset by increased maintenance charges which will ultimately have to be borne by the purchaser. It is considered that the prestige of British engineering depends more on the standard of its products than the price at which they are produced. There is nothing that cannot be made a little " nastier " and a little cheaper. If there are two firms building a machine of the same type and one firm makes a 10 per cent. nastier but five per cent. cheaper job, eventually the firm making the dearer job will survive the other. With regard to the chief designer having a free hand, I am entirely in agreement with Mr. Whitehead that your designer must be given an absolutely free hand, being responsible to the chief engineer only. Having had shops and drawing office experience in about equal proportions since entering the profession in 1908, I make this statement after careful consideration. If your foremen or chargehands are able to teach your chief designer at say £600 or £700 per annum, then he is obviously not worth his salt. The chief designer should be a

man with thorough technical and practical training and should have served his time in the shops and, in addition, should have held the position of senior draughtsman or section leader in the drawing office for some years before being made chief designer. As an exception, and not the rule, advice may with discretion be accepted from the shops. I am not a believer in the old saying that "an ounce of practice is worth a ton of theory" rather I believe "that nothing is so practical as correctly applied theory."

MR. LAWRENCE: I think two words sum up the situation. "Co-operation" and "Co-ordination" are the two essentials. Unless you have co-operation with every department in the works from the drawing office right down to the smallest boy you will not get the results you require. Whether you are employed in quantity production or unit production you must have co-operation and co-ordination.

MR. OWNER: As one of the tribe of designers who are the "villains of the piece" this evening, I should like to suggest something which has doubtless been said before, that a design which achieves its purpose is always a compromise. No designer has a tight cast-iron certainty. He has to compromise, and all successful engineering is made up of successful compromises, taking into account all the circumstances.

I want to quarrel on one or two points; the first point is, I cannot agree that in all cases success is achieved by means of the lowest possible cost. In regard to this point I would point to the success of British aero engineering. That success has been achieved entirely by building up to a standard that has been set for the rest of the world, and I think I may say without fear of contradiction that the British aero engine can defy competition anywhere, and that has not been achieved by reducing costs. I do not mean to suggest that cost is not taken into account; it has to be, but according to the type of production, so will cost, quality, appearance, and other factors (such as in this particular case, weight) have to take their share.

I would like to suggest, with regard to another point which has been raised, that any designer having reached his position should be a man of sufficient breadth of view to effect compromises and take into account all factors; amongst these, the production of the part should bulk very largely. However pretty a design may be, and however easy it is to make, it is not much use unless when made it fulfils its purpose. I would suggest that the designer must take into account the question of cost, but he must not be bound down and limited by the way in which his product is going to be manufactured unless the criterion of cost occupies the first and practically the only place. The designer should keep up to date with the progress of machine tool technique, but he must not, in

my opinion, regard difficulty in manufacture a reason for holding up an improvement in the design of a part. To put the matter concisely, in the aero engine industry we have often asked the production side to do the impossible for us, and they have not only done this, but have come later on many occasions and said they have produced the newly designed part more cheaply than the original. If the designer limited himself we should never make progress or make better articles.

I would further make one little point ; I do agree with a previous speaker that you cannot have every foreman telling the designer how to do his job. I would suggest that no country, no war, no human enterprise in history, has been successfully run by a large committee. Co-operation is really necessary but the designer should not be prejudiced by it. Moreover the man responsible should be the chief production engineer and the discussion should take place between him and the chief designer ; all suggested modifications should be discussed by these two people. I do suggest that after the design is completed and thoroughly tested, the production man should be left alone to produce a reasonable batch of products as alike as peas in a pod. Any improvements necessary should be introduced in the next batch. The designer should see the design is right for a batch, and the production should be given a clear run after that.

MR. WALTON : It has been my experience that many indifferently designed machines from a production standpoint, have been produced successfully, and at a competitive price, as a result of the ingenuity and skill displayed by production engineers. I quite agree with Mr. Whitehead that production engineers can usually overcome all such difficulties brought about by indifferently designed component parts. Success in such instances is only achieved at the expense of prodigious expenditure in equipment. It will, of course, be asserted that all production difficulties are given the necessary attention at the inception of a new design, or when a radical alteration is made to an existing design ; but investigation would bring to light innumerable unfavourable instances. It is one of the important duties of production engineers to foresee and prevent such circumstances. In the creative sphere production engineers encounter obdurate designers. In applying pressure to modifying features of design, the production engineer must have more than a nodding acquaintance with the product to be made, and bring to bear a knowledge approaching or equal to that possessed by the designer. Otherwise, his recommendations will not receive the consideration merited. Such issues are the acid test of ability, and for a production engineer to be successful on a point of equal knowledge, has a lasting effect in cementing a healthy co-operation between the two spheres. Such occasions offer much scope for production engineers to exercise that

understanding of the human element, which is not come by from a proficiency in technical lore. It may be thought by many that such discussions should be unnecessary, provided that those in control have the correct perspective. This attitude, while it may apply to cases which are taken in one's stride, indicates a lack of intimate knowledge of the situations which can arise in the arena of what should be concerted endeavour.

COLONEL PITT : This discussion is of great interest to me as I have had charge of a drawing office for ten years. I now have the shops and the sales as well, and am trying to use my experience in the drawing office to co-ordinate all these. I don't think enough has been made to-night of the experience which can be gained from the sales people who go out and get to know about the faults of machines. Unless you keep in touch with the actual people who use the machines you cannot be sure of sound and economical design or manufacture. So I cannot quite agree with Major Helps that the drawing office have nothing to learn. I think those in it can learn a great deal from talking to people of every possible type who have anything to do with the machines which they design—the works manager, salesmen, or even a crane driver, and the only possible way to progress is by constant close co-operation of all concerned.

MAJOR HELPS : I do not consider that it is the job of the salesman to go round endeavouring to find out if faults have developed in the machine after delivery to the purchasers. This I consider to be the job of the service engineer, but is it not " late in the day " after the delivery of the machine to send and inquire if everything is giving satisfaction, and is not satisfaction more likely to be obtained by the service engineer or other technical representative of the firm definitely obtaining the purchasers' absolute requirements before commencing the design at all ? If anything is drastically wrong the purchaser will obviously let the manufacturer know very quickly. Dual control was proved hopeless in the war and I fail to see how multiplicity of control and ideas can win the industrial war. Rather must responsibility rest on one good man. A draughtsman and chief designer are two entirely different propositions. Your chief designer does not require to be told by chargehands and others what is wanted to cheapen production. He has been through the shops himself. I consider the control of design should rest entirely in the hands of three people, viz. : the chief engineer, the chief designer, and the production engineer, who should co-ordinate the general layout of any design, otherwise you tend to become a " Soviet."

MR. KENWORTHY : Consideration of this subject must necessarily be governed by whether one is considering mass production manufacture or small quantities, and I propose considering the conditions existing under mass production. One good point mentioned by Mr. Ayton is the building of a trial machine to determine what modi-

fications may be necessary to produce that machine economically and to a predetermined figure prior to going into production. Whatever may be the mind behind the design, there is always the possibility that what appears to be desirable on paper may require considerable modification before it can be put into economic production. This can be accomplished by building a trial machine without fundamentally altering the design. Everyone will agree that assembly is cheaper than fitting, consequently it is essential that the greatest attention should be paid to limits in the machining stage, in order to eliminate fitting wherever possible. Not many draughtsmen would claim to be able to complete a design embodying a fair amount of detail, which could go straight into production without some slight alteration. The necessity for alteration is often found after production has commenced. How much better would it have been to have determined the alterations necessary beforehand and the corrected drawings issued before starting production. The best results can only be obtained when there exists the best possible liaison between design and production.

MR. WILLIAMS: We have heard various arguments from both sides, chiefly from the works side, and it seems that there is a preponderance of works people here, but one point appears to have escaped so far, that is that the problems put through to the works by the design office have made us what we are. This important Institution is due simply to the problems we have to overcome. We should give the design side a free hand and they should put their designs up to the works for us to make. The more problems they give us the better engineers we shall be and the more scientific our jobs will become, and incidentally the more scientific and valuable the Institution of Production Engineers will be.

MR. SCAIFE: Mr. Whitehead said he was entirely on the side of the designer. I can see his point of view, that is that if we get out a new design, the first idea that usually occurs to the production staff is to object to any new designs which may mean new methods and if we put the works side on top we should never make any progress in design. On the other hand, if you let the drawing office "rule the roost" you may be making a product for which there is no sale. You must take the salesman's point of view into consideration when making any new design to find out if the new product will sell, that is, if considering the advantages of the new features, it can be made at a price which will find a market.

Major Helps said you ought to rely entirely on your chief designer and he then went on to give his experiences of going into the field for information. All evolution of engineering practice comes from the field, at least that is my experience. If you don't keep your ear to the ground you are not going to make much progress in the office.

I think the whole thing turns on a common sense view of the situation. You find extremely practical men in the drawing office sometimes and sometimes you find an extremely good designer in the shops. I think the whole keynote of the situation is for the head of the organisation to ensure that the best brains for any particular problem are being utilised for his firm. My own scheme is to train apprentices both in the shops and in the office, that is, all our apprentices go through a course of instruction in the works and in the drawing office, and actually the whole of our designers are as equally at home in the works as on the board. I think it is only by that general experience you can get the best features in your design. I should like to take the opportunity of joining in the general appreciation of Mr. Ayton's treatment of this ancient and modern subject of getting the best product at a minimum works' cost.

MR. PEARSON: I would like the President of our new Section to give some indication, if he can, before the meeting closes, on one rather important point. I take it that it would be true to say that we in the Bristol area are not all on mass production. There are also some first class jobbing works, and also people like those in the chocolate and tobacco trades, and I take it that it would open a very good field of view if we tackled some of the problems of these trades. There must be some very good engineers in these trades and they must have many problems. Perhaps our Section President could give some indication whether this Section are out to tackle the problems of these industries.

MR. WHITEHEAD: I am pleased Mr. Pearson raised the point he did. Those are really the types of engineer we want to get together in Bristol. In the West of England we have got so much to talk about apart from motor cars that we ought to get some really good meetings. Some of us on the motor car and aero engine side may be able to help those on the chocolate, printing, and tobacco sides, and I think the interchange of ideas would be very helpful to everybody, and would bring out some new ideas to the advantage of both.

MR. AYTON: I am very glad my paper has been so well discussed. I feel pretty well shot to pieces by the batteries on both sides, but I came prepared and looked forward somewhat gleefully to the experience. I think certain of the speakers rather misunderstood my point of view for I was not talking about producing cheap work. The works of which I am works director in Ipswich have five factories making a great variety of quality products and we sell on quality, but there is one point we have got to remember in connection with this matter; that the British engineering industry cannot exist on this country alone. We have got to sell our products in the overseas markets, against the competition of foreign

firms, some making quality and some inferior goods, but obviously if you are making a quality product, and you can get the price of that product as near as possible to the less good quality product which is on the market, you are going to get in the market, and the lower the price you can make at the bigger the market you get, and this is what we should aim at. I claim that efficiency in every department depends very largely on the team spirit, and I am only suggesting you should get this spirit. I am rather glad to see that quite a number of people take the same view. I am not suggesting you should fetter the designer, but I do think it is a good thing for a designer to get the collaboration and co-operation of the people who actually have to do the work on the job. I think it is absolutely impossible for any designer to keep himself *au fait* with the continual progress which is going on on the production side. I am not suggesting he should consult every foreman, but I do suggest that on questions of improvement in machine design it is a great help to have a conference and hear every point of view and decide what is best to be done. There must be some head, but I do say it is a great help to have the team spirit whether you are on mass production or on ordinary jobbing engineering or whatever you like to call it. After all it is very important with mass production, because once you start on production it is frightfully expensive to have to make alterations. It is far better to get everything right at the very start and be sure, and then go right away, and that surely applies to small quantity production as well as mass production. It is a question of efficiency and that means getting down to a price. I am not talking about cheapness in the sense of meaning cheap and nasty goods, but one must keep one's price down to sell in overseas and highly competitive markets. I think I have dealt generally with the points which have been raised by the discussion, and I don't think I need go into any further detail.

I am very much obliged for the way in which you have received my paper.

SIR ALFRED HERBERT: There seems to me just one very slight point the speakers have missed in this discussion. We have taken into consideration the powers and duties of the draughtsmen and production engineer, works manager, pattern makers, and foundry men and the rest of it, and I am very pleased that the discussion is so interesting and so keen. It seems to me, however, that one person has been left out, and that is the customer. In my experience of design, it is the customer who decides whether a design is good, and the customer who decides whether it will work satisfactorily, and " by jove " the customer soon tells you whether the price is right.

MR. F. LISTER: I think we could not have had a better person than Mr. Ayton to come down and present such a very fine paper.

It produced a very interesting discussion. We can say that from the designer we get the original idea, and from this we get the production and from the production we get the sales, and therefore I think these three must work in co-operation if we want to make a success. I have very much pleasure in proposing a hearty vote of thanks to Mr. Ayton for coming here and giving us this very interesting paper.

MR. KENWORTHY, in seconding the vote of thanks, invited engineers present who were engaged in some of the special branches of production for which the Western district was noteworthy, to come forward and help by giving papers to their new Section of the Institution.

The vote of thanks was cordially adopted.

THE GROWTH OF THE BIG INDUSTRIAL CORPORATION.

Address to the Institution, Manchester Section, by W. L. Hichens.

MR. G. E. BAILEY (Chairman) : I would like to congratulate the Institution upon this wonderful opening of their present session, and I hope that their meetings for the session will not only be attended as this one is, but will also result in useful and interesting discussions to the benefit of their members. The Committee is to be congratulated on selecting to-night this subject, and also on securing Mr. Hichens as their opening speaker. I have had the pleasure of occupying the chair on a previous occasion when Mr. Hichens was speaking before an audience in Manchester, and I can assure you that although you may not agree with all he says, you will be left with no doubt at all as to what his intentions are. Mr. Hichens knows this question from very great experience, derived from operating a very large organisation, and therefore what he has to say to us will not only be said by one who has read a lot about the subject, but by one who has had a lot of experience in running one of these large organisations. I think at the present time that all of us will agree that industry is in a very difficult position, and anything we can learn from people like Mr. Hichens is going to help us to solve this difficult problem. You will recollect that after the war everybody wondered what we were going to do with industry, and that wonderful word " rationalisation " was coined. I am in doubt to-night whether Mr. Hichens is going to deal with " rationalisation " ; the subject of his talk is " The Growth of the Big Industrial Corporation." whether he means by " growth " the number of them, or the growth of the actual companies which have started, I will be very interested to know how he works it out. From my experience a good many have been started, but very few have grown. It is not my intention, nor I am sure, your wish, that I should encroach on your time, and I have great pleasure in asking Mr. Hichens to address us.

MR. W. L. HICHENS : Let me say at the start that it is a very great pleasure to me to be here to-night, because I always like addressing a Manchester audience, not because they agree with me—they probably do not—but because they are really keen on industrial problems. I have chosen to-night a rather difficult subject, " The Growth of the Big Industrial Corporation," and let me say at once to Mr. Bailey that I shall have to deal quite largely with the problem

which is now known as " rationalisation." By that I mean the amalgamation of firms doing a similar class of business with a view to securing greater efficiency and economy, and I have to refer to it because the growth of the big industrial corporation has come about largely through amalgamations or the freeezing out of the smaller businesses.

I should like in the first place to say a word or two about the history of the growth of the " Big Industrial Corporations." Rationalisation is a comparatively modern term—and incidentally a very bad one—and one is rather inclined to think that the growth of big corporations is itself a modern thing, but in point of fact it dates back a long way. Let me give you one or two examples.

I will take the railways first of all. One is sometimes inclined to think that the " rationalisation " of the railways began in the year 1921, which was the year of the Railway Amalgamation Act, but as a matter of fact rationalisation began on the railways over one hundred years ago. The first amalgamation, I think, was the amalgamation of the line which ran from Liverpool to Wigan with the line which ran from Preston to Wigan. They belonged to two separate companies so that an Act of Parliament was involved which aroused considerable opposition. It took the familiar l ne that competition was in the interest of the consumer. However, eventually the Act went through. Now that process of amalgamation went on steadily during the next hundred years of railway history. At one time or another there were no less than 1,000 separate railway organisations in this country. A policy of gradual absorption reduced the number to about 120 by the end of 1913 ; and had it not been for this gradual process which reduced the number to manageable proportions the big amalgamation scheme of 1921, which cut down the number of railway companies from over 120 to four, would not have been possible.

Now the general outline of the scheme is well known to everybody and I do not intend to dwell on it. Broadly what happened was that the railways were converted into a public utility corporation. There are four of them, it is true, which to some extent are in competition the one with the other, but on the whole competition has largely been eliminated and the railways are to-day more or less a monopoly. Because they are a monopoly their profits have been strictly limited and increases in rates and fares require the previous sanction of the Railway Rates Tribunal. As a matter of fact, as everybody knows, the unfortunate railways have not since 1921 been in a position to earn unduly large profits nor have they proposed large increases in rates because they knew if they did it would only serve to decrease the traffic handled. Under their present constitution, then, the railways are a public service corporation run primarily in the interests of the public with their profits limited.

A further extension of that principle was adopted when the London Passenger Transport Act was passed last year and another big public utility corporation was brought into being, which controls the trams and buses as well as the railways throughout the whole area of London. Again its profits are limited and its functions are clearly defined. There is another stage, then, in the growth of these big industrial corporations.

A third example is the Central Electricity Board which came into being in 1927. Its object was two-fold. In the first place to co-ordinate supply and demand and avoid redundancy. How to correlate capacity to effective demand is one of the greatest problems of modern industry and it is a point to which I shall venture to return more than once. That was the first object of the C.E.B.—to co-ordinate supply so that it would not be in excess of demand, and the second was to secure standardisation in supply, to eliminate differences in frequency and voltage. There was a difference of opinion at the time as to whether the C.E.B. was the best way of dealing with the problem, and there are still many people who think that it might have been better handled if a different line of approach had been taken. In the presence of Mr. Bailey I have no intention of entering upon that particular problem but this I will say, that I do not suppose anyone now would wish to unscramble the eggs. The C.E.B. being there, probably everybody will accept it as a fact and make the best of it. So here is another big public utility corporation which has grown up in the last few years.

If one wanted to refer to others, one has only to think of the B.B.C. which has been built up on the same general lines. These are striking examples of the big corporations which have grown up in the last few years, but the same process of consolidation has gone on in other fields as well. Take, for instance, the case of the banks. We know that over a course of years the numerous small banks have gradually been consolidated into the Big Five. Personally I think this consolidation has been a great advantage to the country because when one looks at the multiplicity of banks in the United States one sees one reason why the banking system in America is so weak. The banking system in this country is undoubtedly strong. Sometimes industrialists like myself are inclined to think that their profits are too big, but on the whole it seems to me well worth while that their position should be strong and unassailable financially. Then again we are all familiar with the cotton amalgamation of Messrs. Coats and the soap amalgamation of Lever Brothers. We have followed the building up of the I.C.I. We realise too that there have been important amalgamations among newspapers, and we know that the same process has been at work in the coalfields, the iron and steel industry, and elsewhere. So that, when we look at the history of industrial development, we see that there has been a very large growth of

concentration during the past hundred years or more, and that that process has been extending with increasing rapidity in modern times. That is something we cannot get away from. It is there. It is a fact which faces us. I would call attention to three points.

The first is that this movement towards the big industrial corporation is not confined to this country ; it is world-wide ; therefore there must be some deep underlying cause which is at the back of it all.

The second point is that whereas in their earlier beginnings, as I mentioned in the case of the railways, these consolidations and amalgamations were bitterly opposed, now, so far from being opposed they are encouraged. Consolidations or amalgamations are stimulated and promoted by the Government rather than hindered as they were in the earlier days. Formerly the Anti-Trust Laws in America were designed to prevent these big corporations : similarly there were laws in England to prevent agreements in restraint of trade. Trusts and monopolies were then suspect ; now they are encouraged.

The third point is that the pace of the movement has been and continues to be rapid. It is not a thing of the past, it is going on to-day at an increasing rate in every country in the world, so we cannot therefore escape from it, but are forced to take it into account. The first question which occurs to one is, is it a good thing or is it bad, should it be encouraged as it is being encouraged or should it be discouraged ? Now there are many people who regard this movement with serious misgivings. They look back regretfully to the good old days of private enterprise. They argue that competition is the only safeguard that the consumer can really claim as being effective and I think you will agree there is a great deal of force in the contention. At dinner to-night we agreed that the increased efficiency of the railways in recent times—and I hope you will agree that there is increased efficiency—is due in no small measure to motor competition. There is no doubt that competition is a stimulant. It does cause efficiency. It does ensure a greater consideration to the individual. Again, it is often argued that British industries were built up by the sturdy individualism and spirit of adventure of our forebears, and that it is only by these qualities that they can be maintained. Few people, I imagine, would deny the cogency of this line of argument.

There are, and one must face them, serious objections to the process of co-ordination or rationalisation which is going on at the present time, but before answering the question whether rationalisation is a good thing or a bad one, there is another question we must ask ourselves. Is this form of organisation inevitable or not ? Can we escape from it ? Is it a necessary consequence of our modern environment ? You will agree, I think, that to be successful any

organisation must be adapted to its environment. For example, a monkey to be successful must be able to adapt himself to his environment and climb trees. If in the course of time, he finds himself unable any longer to climb trees, or the trees disappear, he must, evolve himself into something else—a man for example. Inevitably, everything must adapt itself to its environment and we, just as much as anything else, must adapt ourselves to our environment. If our environment changes, we must change with it and adapt ourselves to it—or disappear. Sometimes, of course, we can alter our environment, and thus avoid alteration in ourselves. But if the process of change which is going on is an inevitable form of evolution due to the changing environment around us—then we must bend before the storm or break.

Now I know that many people dislike intensely the idea of change, and it may be that an absence of elasticity and adaptability is one of the serious dangers of modern times. It is perhaps more particularly the besetting sin of advancing years. Let me read you a quotation from one of the leading philosophers of to-day, Professor Whitehead. "The whole of our tradition is warped by the vicious assumption that each generation will live substantially amid the conditions governing the lives of its fathers, and will transmit those conditions to mould with equal force the lives of its children." That I think contains a truth which we ought to consider very carefully.

But, it may be asked, granting that we must adapt ourselves to our environment whatever it may be, unless we can change it, are these great central organisations the necessary adaptation to our modern environment? That, I think, is an important question to ask, and one to which it is essential to find an answer. We have to accept the fact, I think, that the big industrial corporations have been developing with increasing rapidity during the last century. Are they necessary to our modern environment? And, if so, why? I suggest that they are necessary and that the reason is that this structure does in fact conform to the two great forces by which humanity is impelled in modern times. One of these forces is intellectual or moral, and the other is material, and I want to say a word about both.

The first, the one I have called intellectual or moral, is what Professor Whitehead, in his latest book, *Adventures of Ideas*, has called the democratic ideal. That, in his view, is the great intellectual or moral force which has been working in the world and creating its environment during the last 2,000 years. He means by the democratic ideal the conception which is as old as Plato, of the grandeur of the human soul, of the essential harmony of mankind, of the brotherhood of man, in contrast to the rival theories of strife and dissension and individualism. It stresses the ideals

of service and our duty to our neighbour rather than that of individual rights. This ideal in spite of many vicissitudes and many back slidings has been one of the creative forces during the history of civilised humanity. It has slowly created the environment in which it is possible for it to work, and the work of creation is still going on. It has not, of course, been unchallenged : it is challenged in certain countries to-day. There was a period of reaction during the 18th and 19th centuries at the very time when modern industrialism began to develop. This was the heydey of individualism. We recognise it by its watchwords : " Unrestricted competition," *Laissez-faire*, " the higgling of the market," " the survival of the fittest," " Nature rending tooth and claw." These were the signposts of those days, and are still signposts to many of us, but as a matter of hard historical fact they pointed in the wrong direction. They have proved to be quite unworkable. The restraint of individual liberty began at once in the Factory Acts, in the reduction of hours, restriction of child labour, and the like, and this has gone on with increasing force ever since. The democratic ideal leads inevitably, in so far as the basic requirements of humanity are concerned, either towards State socialism or towards the big industrial corporation. I do not personally think that there is a great future in industrial matters for State socialism. The State in my view is already overburdened and it is far better that great public services of this nature should be carried out by public utility corporations with the kind of franchise that I have described.

The second great world force to which I have referred is what is now called very often the growth of technocracy. I dislike the word, which is American, I think, in its origin. You all know what it means, it means the growth of mass production, the increase of mechanisation, which is such a noticeable feature of our modern civilisation. Now, I only want to call attention to two broad points in this connection, which I think establish the position I want to make.

The first point I want to make is this, it is not merely one country that is industrialising itself and where the growth of technocracy is to be observed. It is a feature which is common to the whole world. One hundred years ago, when mechanisation first started, we were the workshop of the world and we supplied other countries with manufactured goods in exchange for raw products and foodstuffs. That is no longer the case and every country is now becoming industrialised. There are many lessons which could be drawn from that but I only want to refer to one. That is, that industrialisation or mechanisation goes ahead very much faster and is much more difficult to control when it is applied to the whole world than when applied to only one country. That is quite obvious. In the old days British industrialists did not have to think much as to whether

the capacity of their plants was excessive ; they took it for granted that the world demand would grow to meet their capacity. Now, that might be true so long as there was only one industrial nation and the rest of the world is buying from it, but if the whole of the world is mechanised, it is obvious that it is extraordinarily difficult, if not impossible, to control the increase of capacity and to correlate it to demand.

The second point is, that in modern times the capacity of machines as well as quantity has been increased enormously so that there is not the same scope for the small unit as they used to be. Here is one simple example which came within my own experience. Cammell Laird & Company, of which company I was chairman, determined to put down a new railway tyre plant to replace three obsolete ones which had a capacity of about 7,000 tons per annum. The new plant was nominally capable of producing 20,000 tons of tyres a year and was actually able to work up to 30,000 tons a year. That is some indication of the tremendous growth in capacity of modern machinery.

The conclusion I would draw is, that it becomes more and more difficult under modern conditions to co-ordinate capacity and effective demand. To my way of thinking this is one of the most serious problems of industry to-day. We are often asked why prices are low ; why things seem to be going from bad to worse. To me, as an industrialist, the main reason why prices are low and unremunerative is that there are too many other workers in the field, that is to say that capacity is so far in excess of effective demand. Let me give you a brief example from my own industry, shipbuilding. It is estimated that a short time ago the capacity of this country was equal to turning out 3,000,000 tons of shipping per year, whilst actually last year I do not suppose there were 100,000 tons turned out, and the capacity is out of all proportion to any reasonably probable demand in the future. I think I can safely leave it to you to give other examples of the same state of affairs.

But admitting that the gradual evolution of the big industrial corporation is inevitable, how is it to be achieved ? What part is the State to play in the matter ? Let us see what is happening, and let me take again the case of shipbuilding first of all. How is the shipbuilding industry trying to cope with this problem of excessive capacity in relation to any probable effective demand ? As you probably know, a body has been established called Shipbuilders' Securities, Ltd., the object of which is to buy up redundant shipyards and close them down. On the whole this body has been fairly successful, for it has acquired a certain number of yards and closed them down. It has also acquired a certain number of berths and closed them down altogether. The funds have been provided by the ship yards which remain in existence, but it is a slow process

and is not altogether a very popular one, because it is regarded, and not unnaturally, in the industry, as being after all only a glorified form of liquidation, since no one is likely to sell his business to "Shipbuilders' Securities" except in the last resort. It cannot be said that "Shipbuilders' Securities" has solved the problem of redundancy, but it has made a valuable contribution. The same problem of redundancy exists in the shipping industry and a similar kind of scheme has been mooted, the suggestion being that a Tonnage Disposal Board should be constituted and financed by tonnage reduction dues which should be collected from national vessels at all ports. Nothing, however, has been done as yet.

Then there is the steel industry, which is a very thorny problem, and there is a good deal of difference of opinion on the subject. It is agreed, I think, that there is an excess of capacity in the country in relation to any probable demand in the near future, and it is also generally recognised that the steel industry ought to reorganise itself. That, I think, is recognised not merely by the Government, but also by the steel industry itself. Two alternatives presented themselves to the Government: one was to give the industry protect on after it had reorganised itself; the other was to give protection first and require reorganisation afterwards. It is quite obvious which was the most attractive to the steel industry. Naturally they preferred to be protected whilst they were making plans for their own reorganisation; and they got their own way, and were protected to the extent of 33⅓ per cent.—no mean protection. However, it does not seem to have been enough. Many are claiming more to-day, and when they are asked what they mean by "more" they say "enough to keep all foreign steel out of the country." That is a perfectly clear and definite answer, but the question is—What have they done to reorganise their own industry? They appointed a committee to consider the question, and that committee produced a report recommending various forms of reorganisation. There was to be a Central Iron and Steel Corporation of Great Britain, and there were to be a dozen or more associations to deal with the different classes of product. The associations were to have power to create a levy for buying up redundant works on the lines of "Shipbuilders' Securities," but actually nothing has been done in this direction. Probably all that will happen as the result of the report is the creation of a number of associations whose main function will be to allocate work on the quota system and to pin prices. All experience shows that the result of such a system is—not to eliminate—but to bolster up—the inefficient. The other alternative of deferring State action until a scheme of reorganising had been adopted by the industry, although perhaps harsh, would probably have been more effective. All one can hope is that the steel industry will evolve some effective scheme of reorganisation for itself, because it is of the first

importance that each industry should accept the responsibility of reorganising itself. It is a mistake that the Government should intervene except in the very last resort. Just as in the case of the railways, the work of amalgamation was in the main done by themselves, so the other leading industries must recognise their responsibilities and reorganise themselves. It would, I suggest, be healthy and beneficial if it were clearly realised that no Government assistance could be looked for, and that each industry must work out its own salvation—with this qualification, that State intervention is justified in the case of obstructive minorities.

I now come to my conclusion. The conclusion I want to draw is that the two great forces of what Professor Whitehead has called the democratic ideal on the one hand and technocracy on the other, which in their conjunction are irresistible, are moving forward slowly towards a new set of conditions. They are creating an environment to which we are bound to adapt ourselves, and to which we are in fact adapting ourselves throughout. That adaptation has taken sometimes the form of State or municipal action (e.g., the Post Office and electric lighting and trams). Sometimes it has taken the form of the big public utility corporation (e.g., the Metropolitan Water Board, Central Electricity Board, and B.B.C.) and sometimes it has taken the form of the big industrial corporations (e.g., the Imperial Chemical Industries). But there is still a large field which is in the transition stage. The growth of the movement during the past century has been remarkable. If we are wise we shall try neither to retard the movement nor to precipitate it unduly. Rather we shall try to adapt ourselves to it. For if the form of organisation is determined in the main by our environment its successful working depends on ourselves. If we seek to apply the conceptions of a non-mechanical age to the modern field of technology, the result is bound to be a failure. If, again, we attempt to apply the principle of individualism in a democratic field, if the urge for private profit and individual advantage is stronger than the claim of public service, if we pay lip service to the one principle and practise the other—we shall crash, for we shall be striking at the roots of civilisation which has slowly been built up during the last 2,000 years.

Discussion.

MR. G. E. BAILEY : Mr. Hichens has given us a very comprehensive and interesting talk on the very difficult subject which he chose, and before opening the meeting for discussion I believe I am expected to say a few words. In doing so I do not wish in any way to take points from those who wish to speak from the audience, and I hope therefore, if I do mention one or two points which anyone had intended to speak about, they will not refrain from doing so.

Mr. Hichens, in putting forward the case of the Central Electricity Board, said he had a certain amount of diffidence in referring to it in my presence. He also said it was formed to regulate the supply and demand and standardise electrical conditions. I might say as regards the electrical industry, that it is what they would like as far as their own industry is concerned. Particularly standardisation of their products, which would enable us to get down to something like manufacturing problems, and if we could only escape from some of the wonderful ideas which some customers get, I think the product would be cheaper, if not more efficient.

Mr. Hichens also said that competition caused efficiency. I agree with him completely, but he made a reference to the railways and said that the railways had learnt efficiency from road transport. I think we could go further and say that uncontrolled competition may create bankruptcy. That may be one of the reasons why the railways are in collusion with road transport, and one is pleased to note that there are prospects of these two coming together with a view to directing supply and demand, so that each may be assured of what he might consider his rightful share of the quota. I would suggest if this could be carried out more in industry, each recognising each others rights, we would probably see an end to a good deal of this wasteful competition we are faced with to-day.

I had hoped that whilst Mr. Hichens referred to the fact that probably some form of Government control was inevitable, he would have indicated that there was still an alternative. To me, it is outstanding that the Government, having given certain facilities by way of tariffs which will control foreign competition, will not be content to stand by for ever and see industry carried on in a wasteful manner which results in business being carried out in a bad way from the point of view of the shareholders, particularly those engaged in that particular industry. I do not see any hope of the conditions of the workers or staff being improved substantially until there is a better getting together and arranging of conditions under which we are to operate. Therefore, it seems clear to me that industry must organise itself, and that the firms engaged in a

particular industry must get together and obtain statutory powers from the Government to carry on their business in an efficient manner. And when I say efficient manner, I mean efficient to all those who are dependent on that industry, from the point of view of the shareholder to the man on the shop floor. I do not see that this is an impossible task—it can be achieved by fuller co-operation, and unless that co-operation is forthcoming I cannot see any alternative but that the Government will interfere as they have done in other directions. I would say definitely that it is far better for an industry to organise itself so that having agreed upon a definite stand, industry would not only control the large majority, but would also control the minority, which is very often responsible for price cutting. Mr. Hichens, this audience is taken from the engineering industry, and whilst I was pleased to note you spoke on the question in the broadest possible manner, I am particularly interested in engineering and I would like to put to this audience this fact, that the engineering industry, which is not organised as I have indicated, and which has much to learn in that way, is manufacturing a product which it sells from 10d. to 1s. per lb., whilst we have an industry like chocolates, which is able to obtain 4s. per lb. I know there are cheap imitations, as there are in engineering, but I am talking of the best. Mr. Hichens—your talk, I am quite certain, has been very much appreciated by the members, who will have an opportunity later on of showing their appreciation.

I have now very great pleasure in asking Sir Walter Kent, who is President-elect of the Institution, to speak.

Sir Walter Kent : Your Chairman said just now that he hoped he would not be taking the words out of the mouth of anyone who had come here intending to put certain questions or to adopt certain lines in respect of this paper. As I only knew some half-hour before I came that I was to say anything at all, I am obviously not one of those ; nevertheless, he has succeeded in saying very much of what I wanted to say to you, but that is the way of a Chairman ! Mr. Hichens, in the extraordinarily deeply thought out and widely applied address that he gave us, touched on such a number of facets of the great problem that confronts civilisation to-day, that it is almost impossible to attempt to make any general reference thereto, except I would like to be permitted to say on my own behalf (and I feel that it is a sentiment very widely shared by you), how grateful we are to him for having given us so much to think about, and to have exhibited so deep an understanding of that very difficult problem. He referred to the difficulty of following the political economist in this matter. Well, I do not wonder, as I was told the other day that a political economist is one who tells you more and more about less and less, until you know everything about nothing ! That was not Mr. Hichens' line at all, he has told

us so much about almost everything, that it is no easy matter to arrange and co-ordinate in one's mind the very serious facts that he has set forth. While I am not, I hope, quite in the position of the jaded school master who, at the end of a long summer term being asked his opinion of teaching, said that it was casting false pearls before real swine, I must admit I find some difficulty in following all his arguments.

I would respectfully suggest that this great question of massing industry depends greatly for its success upon whether in so doing you are placing that industry more or less under a species of Government control, that may introduce that somnolence that is absolutely death to any individual effort. I think that in any building up of the mass of industry out of a number of smaller units, you must keep in mind the vital necessity of preserving that individual effort upon which the success of everything in this life depends. I think that is rather illustrative—and I hope Mr. Hichens will not think me rude in saying so—even in the railways. While he said that railways had made the effort when the competition of the road began to press, was it not because the railways had their own spheres of operation in which they were comparatively secure, that prevented them from seeing far enough ahead to make the railways what they might have been, and we hope they will be, because railways are as necessary to us as is road traffic? Contrasting the railways with the banks, Mr. Hichens described how the banks have come down to the five big banks, but they retain that element of competition and in that I think lies the whole difference. Another example is our telephone system, which is said to be the worst in the world, I believe; also for the reason that it is not subject to the stimulus of competition that is so essential; and therefore I do respectfully suggest to Mr. Hichens that the broad line of demarcation lies along that path, on the one side of which you retain the incentive to individual effort, and on the other where you are lulled to a feeling of security because you think you are more or less procuring your job through a benevolent Government.

Before I sit down, may I be permitted, as your President-elect, to say how tremendously I am "bucked" by seeing such a wonderful audience as I see here in Manchester to-night. If our other sections all over the country can do relatively as well as you are doing here, it says very much for the earnestness of the production engineer. With that earnestness so much is concerned, and is so ultimately bound up with the theme of Mr. Hichens' lecture: because without the organisation of large bodies in industry, that research work—that work of the production engineer which is only possible in a big works—could not be done. That is, I think, one of the aspects where rationalisation or amalgamation of different firms has a very great advantage, and I am delighted to see that Manchester has not

forgotten the old saying " What Manchester thinks to-day, the rest of the world thinks to-morrow." Manchester does believe in the production engineer, as is shown by the splendid audience I have the pleasure of seeing before me to-night.

MR. HEWITT : There are a number of points I would like to put before the lecturer. The first question deals with the organisation of the medium-sized corporation. I am employed by a company of factory organisation consultants and, naturally, in such a type of business one goes into various types of concerns and various industries up and down the country, and my experience has proved that a number of these large corporations only exist on paper ; the units of these organisations, in many cases, go on in their own humdrum way, pursuing narrow channels, and while they rejoice in a high-sounding title, they have taken no steps to organise themselves to meet the aims and ideals of the corporation. I am convinced that the growth of many businesses simply means duplication of everything : six typists instead of three, 12 chasers instead of six, and one can go further than that and say the introduction of an up-to-date inspection staff to inspect things that did not need inspection in the first place. I say that quite frankly, because in going into these various concerns I have been surprised at the lack of organisation that exists in the ordinary type of concern and certainly in the large corporations.

Another point is this. In the organisation, or the bringing into being of the large corporation we lose the family spirit. I think that loss of the family spirit is responsible for much of the labour trouble at the present time.

MR. HICHENS : In regard to the first point I agree with what the speaker said and would just say a word with regard to the second. I think it is quite possible that you do lose something of the family spirit, but at the same time I think it is possible to exaggerate its advantages. If you cast your mind back a hundred years, when there were large numbers of very small units working under extremely unsatisfactory conditions, the family business was in its element, but, on the whole, the condition of labour to-day is very much better under the big organisations that we have than under those small organisations which were a feature of the past. I do not wish to minimise what they did, but I feel that there is no reason in the world why a big organisation should not be managed as well and as sympathetically as the smaller organisation with which we were familiar in the past. It is a question of taking the necessary trouble to do it and I cannot think that it is a real objection to the advance of the big corporation that I have outlined to-night.

MR. HICHENS, replying to a question by Mr. Hague as to where the movement was leading, said : This is an extraordinarily

difficult question to answer. What I have been trying to say is, that as a result of a quite inevitable tendency, we are making in a certain direction whether we like it or not, and secondly, we have got to make the best of these conditions and it depends on us whether we make a success or whether we do not. Sir Walter Kent has referred very sympathetically to competition, and up to a point I agree with him, but it does not seem to me that under modern conditions competition can be, or will be, the be-all and end-all of everything. It is quite true that efficiency has been and will be stimulated by competition, but I cannot believe that it is the only force that is going to stimulate efficiency. My own belief is that people will work as efficiently and as well as they can in these public corporations—they will regard their work as a form of public service. I do not for an instant believe that a doctor does his best for a patient merely because he is afraid that that patient will go to someone else. It seems to me that one tendency of the future will be that much more than to-day people will regard their work as a service they owe to the community in which they dwell and not merely as a means of getting as much out of the community as they can. I do not picture a condition in which everything is run by big corporations and nothing else. As I see it, it is only the big basic services that will be run in that way. There will always be a large and possibly an increasing number of small services which can be best run by small organisations. To-day, I think, most of us know that there are a great many things which can be produced more efficiently and more cheaply by the small man than they can by the big corporation. I do not imagine that will disappear altogether. My point is that the field of the big corporation will, through force of circumstances, tend to increase and that there is no reason to suppose that these services will be inefficiently run.

MR. LESLIE: It seems to me in listening to Mr. Hichens' outline of the growth of the big corporation that the policy is one of negation. I think we in the engineering industry generally hope that with the growth of these corporations we shall get some forward policy with a view to creating more demand, rather than restricting capacity. The great trouble to-day is the lack of demand and the consequent unemployment in all ranks, and if we accept that position and go ahead with the policy of restricting capacity, then I can only see that there will be increased unemployment, and probably inefficiency within the industry at the expense of the population as a whole. If we only had to look at our own country, on the assumption that we were suffering because we were at one time the producers of the world in certain respects, then that policy would appear to me to be more acceptable, but having in mind that other nations not similarly dependent on export are suffering to an even greater

extent, then it seems to me that the policy of restricting capacity is wrong if carried out to an unlimited degree. I feel that these corporations should use their influence to create new markets and new outlets, so as to engage more people, rather than shut down. There is another aspect. It seems to me that there is a tendency in some directions for the corporations not to be wholly disinterested about the individual units of the organisation. If we could think that the only redundant capacity to be shut down would be inefficient capacity, then I think we should have some assurance as to the ultimate benefit.

MR. HICHENS: I agree very much with what the speaker has said. My point was that the first thing we have to do is to correlate supply and demand. To-day, I think, there is an excessive capacity which must be reduced. But I do not want to leave it at that; the ultimate object must be to increase demand. My point rather is that you can only increase demand in the long run if you get greater efficiency, and often this can only be secured through the bigger forms of organisation.

MR. RATCLIFFE: I have listened with much interest to the points which the lecturer has laid down, but I have been somewhat disappointed that in his tracing of the development of the large industrial corporation he has omitted to mention what he thinks is going to be the fate of those millions of men who have not a job to go to. What is going to become of the large and tremendous reserve of labour that is knocking at the gates of industry thirsting for a job? A further point is, take all that has been devoted to education—this college of technology is turning out its dozens of brilliant minds keen on development with a view to rendering service to the professions and the industries of this country; our colleges and universities are turning out their tremendous quotas; and immediately they leave the colleges and universities there is not a niche for them to fill. Mr. Hichens seems somewhat to doubt what the ultimate development will be. In the old days work was more of a pleasure, people took a keener interest in it, but alas to-day men are not finding the same delight in their contribution to the industry of the country. Perhaps State socialism will have to come.

MR. HICHENS: As regards Mr. Ratcliffe's first point, I am afraid that the problem of unemployment created by mechanisation is too vast for me to consider now. I will merely say that you cannot put the clock back and destroy machinery. Means must be found to distribute the leisure created by machinery more sensibly. Mr. Ratcliffe also suggested that men took a greater delight in their work in the days before machinery was invented. I am frankly sceptical about that. The cottage industries were insanitary and sweated and far more unpleasant than a modern factory. Moreover,

on the whole, drudgery in those days was much greater because the chief contribution of machinery is that it has provided a substitute for manual toil. As to the advent of State socialism, I will venture no prophecy, but I would point out that public utility corporations are just as effective as State-run organisations. The B.B.C., for example, would be no more efficient if it were a Government department. But there are certain definite advantages in independence of State control which it would be out of place to discuss now.

A cordial vote of thanks to Mr. Hichens concluded the proceedings.